SYMPOSIUM FF

Advanced Devices and Materials for Laser Remote Sensing

March 29 - 31, 2005

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* Invited paper

SESSION FF1: Solid State Lasers
Chairs: Farzin Amzajerdian and Dennis Killinger
Tuesday Morning, March 29, 2005
Room 3020 (Moscone West)

8:30 AM *FF1.1
Laser Development at Q-Peak for Remote Sensing.
Peter Franklin Moulton, Q-Peak, Inc., Bedford, Massachusetts.

In this talk, we will review our nearly 20 years of efforts to develop lasers for remote sensing and then provide a detailed discussion of some recent activities. Included will be a description of tunable systems based on Ti:sapphire lasers for application to water vapor and ozone DIAL sensing. We will also describe several tunable infrared sources based on optical parametric oscillators for mid- and long-wave infrared DIAL sensing and diode-pumped, short-pulse lasers for precision ranging and altimetry. Finally, we will describe single-frequency, high-power UV lasers for application to wind sensing via direct detection of Rayleigh-scattered light.

9:00 AM *FF1.2
Recent Studies on Diode Pumped 2 Micron Lasers. Kazu Asai[1], Atsushi Sato[1] and Kohei Mizutani[2]; [1]Graduate School of Engineering, Tohoku Institute of Technology, Sendai, Japan; [2]National Institute of Information and Communications Technology, Tokyo, Japan.

Tm and Ho-codoped lasers operating at a wavelength of 2 m are attractive for coherent Doppler lidars and differential absorption lidars because of eye-safety, a high-energy storage capability, and a narrow linewidth in Fourier-transform-limited operation. We have made experimentally comparative studies of laser operations using several Tm and Ho-codoped laser crystals, i.e. Tm,Ho:LuLiF4 (LLF), Tm,Ho:LuAG, Tm,Ho:YLF, Tm,Ho:GdVO4, in normal mode and Q-switched mode. It was founded, as a result, that Tm,Ho:LLF crystal might be one of the most promising one with higher output energy, higher laser efficiency. It is getting more important, on the other hand, how to suspend a parasitic oscillation in high-energy Q-switched lasers and amplifiers due to its high gain. As well known, a cylindrical laser rod is usually used to be pumped symmetrically. It is needed some improvement for the rod to suspend the parasitic oscillation trouble. To resolve this, we proposed a novel design of the pump head using a triangular-prism laser rod in order to achieve both parasitic-oscillation-free operations and efficient conductive-cooling. The results of simulations of pump intensity distributions in the laser rod are presented, and the laser performance in normal-mode and Q-switched operations were obtained. In this paper, we would describe on experimental results both on comparative studies between above four crystals and on the novel parasitic-oscillation-free all solid state 2 micron laser.

9:30 AM *FF1.3
Novel Laser Architectures Developed at Coherent Technologies Inc. for Remote Sensing Applications.
Mark W. Phillips, Coherent Technologies, Inc., Louisville, Colorado.

This paper provides an overview of novel laser technology being developed at Coherent Technologies, Inc. (CTI) for long-range remote sensing of hard targets and distributed targets from ground based and airborne platforms. In all these applications, the need for high beam quality and efficient high power operation is paramount. For many of the applications, it is also critical to control and measure frequency content of the emitted and collected light to a high degree of accuracy (sub-kHz for velocity and vibration imaging, and sub-MHz for most DIAL-type measurements). In this paper, we describe the status of rapidly step-tunable single frequency lasers (60GHz/ms) and variable pulse format high power transmitters for range-resolved, micro-Doppler imaging of rapidly moving objects. The rapidly tunable single frequency laser sources allow full correction in coherent-based laser sensors for Doppler frequency shifts between the sensor and the target, including between objects in low earth orbit. The residual frequency spectrum of return light from the target can then be probed in detail using the waveform-agile transmitter to determine high-resolution rotation and vibration signatures. For DIAL type-applications, CTI is developing tunable sources providing several watts of power in the mid-wave and long-wave IR, based on optical parametric oscillators and amplifiers pumped by high power, rapidly-tunable Cr:ZnSe lasers. This architecture provides a practical way of addressing multiple wavelengths across the IR bands of interest in a repeatable manner, using a sensor with no moving parts. The paper also describes CTI's activity in fielding airborne remote chemical sensors, including the recent deployment of a mid-IR chemical sensor based on parametric oscillators pumped by fixed frequency Nd:YLF lasers, and the development of a dual channel two-micron laser-based instrument for CO2 sensing. In terms of broad-impact laser activity, the paper describes the development at CTI of high power (100W-class), high efficiency self-imaging waveguide lasers and amplifiers that provide a simple means for converting the low brightness output from laser diode bars into the high brightness output of near-diffraction-limited CW and pulsed laser sources. Sources are being developed at 1, 1.5 and 2 microns to support multiple coherent and direct detection remote sensing applications. These devices, in combination with fiber-preamplifiers, are expected to provide a compact, robust, and practical solution for fielding a wide variety of future lidar systems on airborne and space-based platforms.

10:30 AM *FF1.4
Laser and Nonlinear Optical Materials for Laser Remote Sensing. Norman P. Barnes, Langley Research Center, Hampton, Virginia.

NASA remote sensing missions involving lasers and their economic impact are outlined. Potential remote sensing missions include: green house gasses, tropospheric winds, ozone, and ice cap thickness. Systems to perform these missions presently use lanthanide series lasers and nonlinear devices such as second harmonic generators and parametric oscillators. Demands these missions place on the laser and nonlinear optical materials are discussed from a materials point of view. Methods of designing new laser materials to meet these demands are presented.

11:00 AM FF1.5
Robust, Efficient, Optical-Damage-Resistant, 200 mJ Nanosecond Ultraviolet Light Source for Satellite-Based Lidar Applications. Darrell Armstrong[1] and Arlee Smith[2]; [1]1128, Sandia National Labs, Albuquerque, New Mexico; [2]1128, Sandia National Labs, Albuquerque, New Mexico.

Conventional wisdom contends that high-energy nanosecond UV laser sources operate near the optical damage thresholds of their constituent materials. This is particularly true for frequency converters like optical parametric oscillators, where poor beam quality and high fluence destroy crystals and optical coatings. The collective disappointment of many researchers supports this contention. However, we're challenging this paradigm by developing high-energy nanosecond UV sources that are efficient and resistant to optical damage. Based on sound design principles incorporating thorough numerical modeling and rigorous laboratory testing, our sources generate 8-10 ns 190 mJ pulses at 320 nm with fluences ≤ 1 J/cm^2. Using modified but otherwise conventional Nd:YAG lasers, we achieve near-IR to UV conversion efficiency exceeding 21%. Achieving high UV pulse energies, high conversion efficiency, and resistance to optical damage, is no accident. During the past decade, Sandia National Labs has developed comprehensive numerical modeling capabilities for characterizing nonlinear optical devices, and these models have been extensively tested by well-characterized measurements. One result of this effort is the development of quasi-monolithic image rotating optical parametric oscillators. These oscillators combine image rotation with birefringent phase matching to produce high quality signal beams, and they do so while accommodating large diameter pump beams. The result, which contradicts conventional expectations for optical resonators, is high Fresnel Number cavities with good beam quality that produce high pulse energies with low fluence. Sandia has employed this nonlinear-optical technology as the core component of proof-of-concept experiments to demonstrate tunable, efficient, 200 mJ UV light sources suitable for satellite-based ozone DIAL. While we've succeeded in building a robust source of high-energy tunable UV light, the limited selection of well-developed nonlinear crystals restricts application of our technology to only portions of the UV to near-IR range. From an end-user's standpoint, vacuum UV and mid-IR remain difficult or impossible for most high-energy applications. For example, higher-order absorption in the crystal beta barium borate compromises generation of high-energy UV below 300 nm. For longer wavelengths, poor conversion efficiency and idler absorption in the 3-5 micron range limit the usefulness of crystals such as lithium niobate and potassium titanyl arsenate. The only solution is to replace less-expensive Nd:YAG pump lasers with costly two-micron lasers required to pump expensive crystals like zinc germanium phosphide. Unfortunately, there appears to be no significant effort underway to develop new crystals to address these shortcomings. Availability of crystals having greater transmission ranges and higher conversion efficiencies could dramatically expand the practical use of laser remote sensing.

11:15 AM *FF1.6
Development of Fluorescence-Based LIDAR for Biological Sensing. Mikael Tiihonen[2], Valdas Pasiskevicius[2], Fredrik Laurell[2], Per Jonsson[3], Fredrik Kullander[3], Torbjorn Tjarnhage[4], Melker Nordstrand[4], Par Wasterby[4] and Mikael Lindgren[1,3]; [1]Department of Physics, Norwegian University of Science and Technology, Trondheim, Norway; [2]Department of Physics, Royal Institute of Technology, Stockholm, Sweden; [3]Department of Sensor Technology, Swedish Defence Research Agency, Linkoping, Sweden; [4]NBC Defence, Swedish Defence Research Agency, Umea, Sweden.

This presentation presents the on-going development of UV-lasers and a detector system for fluorescence based LIDAR system. A compact parametric oscillator (OPO) with intracavity sum-frequency generation (SFG) to generate 293 nm UV laser irradiation, was developed. The OPO/SFG device was pumped by a 100 Hz Nd:YAG laser (1064 nm) of own design, including subsequent second harmonic generation (SHG) in an external periodically poled KTiOPO4 (KTP) crystal. The whole system could be used to deliver more than 30 microJ laser irradiation per pulse (100 Hz) at 293 nm. The UV laser light was introduced in an optical fiber attached to a sample compartment allowing detection of fluorescence emission using a fluorescence detector system. The spectral detection part of the system consists of a grating and a photomultiplier tube array with 32 channels, which measure fluorescence spectra in the wavelength band from 300 nm to 650 nm. The detector is designed to measure laser induced fluorescence from single laser pulses and has been tested by measuring fluorescence of simulants of biological warfare agents. The solutions were excited with laser pulses at the wavelengths of 293 nm and 337 nm.

11:45 AM FF1.7
Abstract Withdrawn

SESSION FF2: Fiber Optics and Semiconductor Lasers
Chairs: Astrid Aksnes Dyrseth and Kasu Asai
Tuesday Afternoon, March 29, 2005
Room 3020 (Moscone West)

1:30 PM *FF2.1
Chip-Scale High Power Microstructured Fiber Lasers.
Nasser Peyghambarian, Optical Sciences Center, the University of Arizona, Tucson, Arizona.

Short length, centimeter-size phosphate fiber lasers have been demonstrated that generate more than 9.3W multimode and 4.0W single mode output power, producing record powers of more than 1.33W/cm. Also, microstructured fiber lasers made of phosphate glass with Er-Yb-codoped cores were fabricated and generated more than 3 W cw output power at 1.5$_\mu$m. Most high power fiber lasers use silica fibers with lengths of several or several tens of meters. It is impractical for these fiber lasers to be integrated into a very compact device, such as on a chip or even on a small board. In addition, when single frequency output is needed, these long fiber lasers become an unsuitable player due to difficulties in selecting one frequency from their densely spaced longitudinal modes. Centimeter-size fiber lasers promises single mode and single frequency operation. However, the maximum output power of a cm-long fiber laser is mostly limited to the milliwatt level due to difficulties in increasing ion doping concentrations in the fibers and achieving high pump absorption with double-cladding-pump scheme. By solving these problems, we were able to boost the output power from cm-long fiber lasers by more than one order of magnitude. The phosphate glasses used for fiber fabrication have high solubility of rare-earth ions and low clustering effects, which allows us to increase the concentration of Er^{3+} and Yb^{3+} ions without enhancing the detrimental quenching processes. We obtained up to 9.3W power from the multimode fiber laser with $M^2<3.5$ and 4.0W from the singlemode fiber laser with $M^2<1.2$. A new class of microstructure fibers (also called holey fibers or photonic crystal fibers) was made also using phosphate glass. The design of the microstructured fibers was based on the concept of effective index guidance created by periodic triangular arrays of air holes forming the inner cladding. The core region was formed by one or a few unit cells made of solid doped glass in the center of the stacking structure, while the inner cladding was formed by undoped hollow cells. The solid central region could be viewed as missing one or a few air holes in the otherwise periodic air hole array, thus forms a local defect for wave guiding. The holey fiber provided more than 3 W of cw output power at \$$\sim$1.5$_\mu$m. This work is supported by the Air Force Office of Scientific Research through MRI program No. F49620-02-1-0380.

2:00 PM *FF2.2
Coherent Combining of Fiber Lasers and Amplifiers.
Monica L. Minden, Communications and Photonics Laboratory, HRL Laboratories, LLC, Malibu, California.

The prospect of combining multiple fiber lasers or amplifiers has received much recent attention because it offers the promise of power scaling the attractive coherence, waveform flexibility, efficiency, and ruggedness of fiber lasers. Three often confused approaches have emerged. The first and oldest approach, first experimentally demonstrated only five years ago, is that of a phased amplifier array with a master oscillator and actively phase-controlled amplifiers. More recently there has been a flurry of activity demonstrating a second approach; parallel oscillators which form a compound cavity with some set of spectrally congruent modes. A third approach arose when it was found that the physics of self-organization can be employed to make use of saturation nonlinearities in the oscillators, allowing large numbers of them to spontaneously form coherent states without any active control. Each approach best suits different but perhaps overlapping potential applications and each asserts its own unique challenges. For example, active control of well-designed amplifiers permits high quality pulsed, single-frequency, and other waveform specifications to be maintained. However, active electronic control becomes prohibitively complex when very large numbers of amplifiers are required. Passively combining parallel oscillators is simple when a single spatial mode, but not a specific temporal profile, is required, but theories of compound cavities foretell difficulties for large number scaling. Coherent combination via self-organization is not predicted to have a limit on the number of elements, but it does require a substantial and suitable nonlinearity, and the implemention of proper connectivity in realizable optical components is a challenge. Some examples that will be discussed from our work at HRL include: (1) Active phasing using current modulation of the pumps to control fiber amplifier phase, without additional optical phase-shifter components, operating with up to seven lasers totaling seven watts; (2) A passive 200 Watt (cw) coherent combination of two Yb fiber lasers; (3) Passive phasing of up to nine lasers in an all-fiber coupler; (4) Passive phasing of fiber-coupled semiconductor amplifiers.

2:30 PM FF2.3
Development of an All-Fiber Coherent Laser Radar for Precision Range and Velocity Measurements.
Diego F. Pierrottet[1], Farzin Amzajerdian[2] and Frank Peri[2]; [1]Coherent Applications, Inc., Hampton, Virginia; [2]NASA Langley Research Center, Hampton, Virginia.

An all fiber coherent laser radar system capable of high resolution range and line of sight velocity measurements is under development with a goal to aide NASA's new Space Exploration initiative for manned and robotic missions to the Moon and Mars. Precision range and velocity data are key to navigating planetary landers to the pre-selected site and achieving autonomous safe soft-landing. By employing a combination of optical heterodyne and linear frequency modulation techniques and utilizing state-of-the-art fiber optic technologies, a highly efficient, compact, and reliable laser radar suitable for operation in a space environment is being developed. The all-fiber coherent laser radar has several important advantages over more conventional pulsed laser altimeters or range finders. One of the advantages of the coherent laser radar is its ability to directly measure the platform velocity by extracting the Doppler shift generated by the platform motion. The Doppler velocity measurement is about two orders of magnitude more accurate than the velocity estimates obtained by laser altimeters using the rate of change in range. Another advantage is continuous-wave operation that allows the use of highly efficient and reliable commercial-off-the shelf fiber optic telecommunication components. This paper will describe the design and operation of this laser radar sensor and discuss its projected performance. A laboratory breadboard system has already been developed as a step toward a flight prototype. The experimental data representing the potentials of this laser radar system will be reported.

2:45 PM FF2.4
Multipurpose Fiber Injected- Micro-Spherical LIDAR System. Hossin Ahmed Abdeldayem[1] and Tracee Jamison[2]; [1]Code 554, NASA-Goddard Space Flight Center, Greenbelt, Maryland; [2]Code 562, NASA-Goddard Space Flight Center, Greenbelt, Maryland.

A technological revolution is occurring in the field of fiber lasers. Over the past two years, the level of power has increased from $\sim$100 watts to nearly 1 kilowatt. We are developing a novel fiber laser system, which is a satellite-based LIDAR transmitter of multi-lines. The system is made of a hollow fiber filled with μ-spheres doped with lasing materials. Each sphere has its inherent optical cavity, which makes the system a cavity free and in the same time, emits multi-laser lines for simultaneous multi-task operations. The system is also rugged, compact, lightweight, and durable. Our earlier studies on m-spheres doped with different laser dyes demonstrated the emission of extremely fine laser lines of less than 3 Ao line-width, which are of interest for spectroscopic applications, sensing, imaging, and optical communications. Individual dye-doped μ-spheres demonstrated a lasing resonance peaks phenomenon in their fluorescence spectra of linear and nonlinear features that do not exist in the bulk dye solutions. Each individual μ-sphere acts as a laser system with inherent cavity, where the fluorescence line suffers multiple internal reflections within the μ-sphere and gains enough energy to become a laser line. Such resonance peaks are dependent on the sphere morphology, size, shape, and its refractive index. These resonance peaks are named structural resonance, whispering modes or whispering gallery modes, creeping waves, circumferential waves, surfaces modes, and virtual modes. All of these names refer to the same phenomenon of morphology dependent resonance (MDR), which has already been described and predicted precisely by electromagnetic theory and Lorentz-Mie theory since 1908. The resonance peaks become more obvious when the particle size approaches and exceeds the wavelength of the laser used and the refractive index of the particle is greater than that of the surrounding medium. The different dyes doped in polystyrene spheres generate broad spectrum of laser lines ranging from 330nm to 1.53 mm for sensing biomaterials, minerals, or atmospheric applications. A proper mixing of these spheres can be used to build a single LIDAR system for multi-functional purposes such as wind speed measurements, chlorophyll mapping, ice melting studies, ocean temperature measurements, etc. The system is designed by injecting the mixture of the dye-doped spheres into a hollow transparent glass fiber. The fiber is pumped by an array of diode lasers. The lasing modes are being guided through the cladding of the hollow fiber. One end of the fiber is totally reflective, while the other end is fully transparent to allow all the guided light to travel only through one end of the fiber, where the laser lines can be separated by a grating.

3:30 PM *FF2.5
Development of Mid-IR Lasers for Laser Remote Sensing. Siamak Forouhar, Alexander Soibel, Kamjou Mansour and Gary Spires; In Situ Instruments Systems, JPL, Pasadena, California.

There is an existing need in JPL and in NASA for development of mid-IR lasers, such as Quantum Cascade (QC) lasers, for in-situ and remote laser spectrometers. Mid-IR, compact, low power consumption laser spectrometers have a great potential for detection and measurements of planetary gases and biological important biomarker molecules such as H2O, H2O2, CH4, and many additional chemical species on Mars and other Solar system planets. Another potential application of QC lasers for future NASA mission is in high power remote Laser Reflectance Spectrometers (LRS). In LSR instrument, mid-infrared lasers will act as the illumination source for conducting active mid-IR reflectance spectroscopy of solid-surfaced objects in the outer Solar System. These spectrometers have the potential to provide an incredible amount of information about the compositions of surfaces in the outer Solar System. In this work, we will discuss our current effort at JPL to advance QC lasers to a level that the laser performance, operational requirements and reliability be compatible with the instruments demands for space exploration applications.

4:00 PM *FF2.6
MEMS Baser Tunable External Cavity Semiconductor Lasers. Ruslan Belikov and Olav Solgaard; Electrical Engineering, Stanford University, Stanford, California.

External cavity semiconductor lasers are ubiquitous in remote sensing and high-precision instrumentation because of their low cost and relatively narrow and stable laser line width. Typically the external cavity is constructed using traditional opto-mechanical components, but MicroElectromechanical Systems (MEMS) provide means for smaller, faster, and less expensive solutions. In this talk we describe external cavity semiconductor lasers that employ microfabricated gratings for tuning. The microgratings are substantially different from traditional gratings in that they are tuned not by rotating the grating as is traditionally done, but by actuating the individual elements of the grating. The direct consequence is that the maximum displacement within the grating is on the order of a wavelength, which means that the tuning speed can be increased and the size of the support structure decreased.

SESSION FF3: Laser Diode Pump Arrays and Advanced Materials
Chairs: Henning Leidecker and Lhadi Merhari
Wednesday Morning, March 30, 2005
Room 3020 (Moscone West)

8:30 AM *FF3.1
Solutions and Reliability of High Power and High Brightness Diode Laser Modules. Christoph Ullmann and Volker Krause; Laserline GmbH, Muelheim-Kaerlich, Germany.

High brightness, high power diode lasers with several kW are already used in high volume in material processing applications. The diode lasers have proven their robustness in 3-shift industrial environmental conditions with very high uptime. This presentation will give an overview about the capability of high power diode lasers for new applications focussing on design concepts as well on reliability and lifetime aspects. The design concept of high power diode lasers will be presented, explaining the stack design with micro channel cooler, beam shaping to increase beam quality. Furthermore, different concepts of increasing power by wavelengths and polarisation coupling will be explained. Based on these principals different direct (free space) and fiber-coupled diode lasers up to multi kW-solutions will be shown (e.g. diode laser modules with 300 W @ 40 mm mrad single wavelengths or 6.000 W @ 150 mm mrad wavelengths coupling). Concepts of single and multi diode laser systems up to 100 diode laser modules will be explained. Reliable diode laser systems are important for future success of this technology in different applications. Failure behaviour of high power diode lasers and aspects to influence lifetime (operation conditions, system set up) will be explained. Actual lifetime data shows lifetime of 20.000 to 30.000 hours and multi Mshots even at high power levels. Mean time between failure of more than 500.000 hours are standard for industrial applications. It will be explained how to build system configurations with stack management, teleservice and other sensor techniques to avoid or minimize system down time. Future developments of high power diode lasers will be mentioned.

9:00 AM *FF3.2
Characterization of Exotic Material Heat Sinks for Laser Diode Arrays. Edward Stephens, Cutting Edge Optronics, Northrop Grumman, St. Charles, Missouri.

Low duty cycle, high peak power, conductively cooled laser diode arrays have been manufactured for several years by a number of different vendors. Typically these packages have been limited to a few percent duty cycle due to thermal problems that develop in tight bar pitch arrays at higher duty cycles. Traditionally these packages are made from some combination of copper and BeO or Tungsten/copper and BeO. Trade-offs between thermal conductivity and CTE matching are always made when manufacturing these devices. In addition, the manufacturability of the heat sinks plays a critical role in creating a cost effective, high performance solution. In this discussion we examine several different exotic materials that have been manufactured and tested as heat sinks for laser diode arrays.

9:30 AM *FF3.3
Investigation of IceSAT Solid State Lidar Anomalies. Henning W. Leidecker, NASA Goddard Space Flight Center, Greenbelt, Maryland.

The NASA/GSFC IceSAT Project launched in 2003 with the primary mission of measuring seasonal and secular changes in the height of ice fields, especially in Greenland and Antarctica, for five years. This is being accomplished using a LIDAR system employing 5 ns long pulses of 1064 nm light at a repetition rate of 40 Hz, imaged into spots of some 70 m diameter, spaced some 140 m apart. Correlation methods are used to attain ice field heights with an uncertainty that has been as small as 2 cm. The design uses a three stage sequence of YAG slabs: oscillator, pre-amp, and amp; each YAG is pumped with laser diode arrays. The final beam is passed through a doubler crystal which converts about 25% of the beam into 532 nm radiation, which is used for measurements of cloud and aerosol density versus height. Preflight estimates of the returned signal strength led to a design requirement of 75 mJ for the 1064 nm beam and 25 mJ for the 532 nm beam. Preflight estimates of the rate of decrease in the brightness of the laser diode arrays suggested that the laser system would remain sufficiently intense to give a good signal to noise ratio for only about 1000 days. Therefore two lasers were needed to reach the desired lifetime and a third laser was added as a guard against unforeseen failure modes. The first laser operated correctly for 36 days and then stopped pulsing without warning. Both ground testing and analysis of flight data point strongly to the cause being the sequential rupture of gold bonding wires in one of the laser diode arrays, hugely accelerated by intimate contact with indium metal: the gold-indium intermetallic compound that forms is brittle, and the bonding wires failed by fatigue induced by the 100 A per pulse current spikes applied at 40 Hz. The brightness of both beams decreased by some 30% during these 36 days of operation. On the positive side, the signal return was substantially larger than the pre-flight estimates, indicating that useful science can be obtained with a few millijoules in either beam. The second laser operated correctly, for more than 120 days during three campaigns of roughly a month each, before the intensity of 1064 nm beam decreased to about 5 mJ and the intensity of 532 nm beam decreased to below 1 mJ. At these levels, some useful science is still possible. Analysis carried out during the campaigns of the second laser has shown that the decrease in intensity of both lasers one and two has been accompanied by an increasing source of heating-power on the entrance and/or exit surfaces of the doubler crystal, or within it. This is consistent with increasing optical absorption developing in the doubler crystal.

10:30 AM FF3.4
Reliability of Long Pulsewidth High Power Laser Diode Arrays. Byron L. Meadows[1], Farzin Amzajerdian[1], Bruce W. Barnes[1], Nathaniel R. Baker[2], Renee S. Baggott[3], Upendra N. Singh[1] and Michael J. Kavaya[1]; [1]NASA Langley Research Center, Hampton, Virginia; [2]Lockheed Martin Engineering and Science Company, Hampton, Virginia; [3]Science and Technology Corporation, Hampton,

Virginia.

Laser remote sensing systems typically rely on conductively cooled, diode-pumped solid state lasers as their transmitter source. Consequently, it is crucial to address reliability issues associated with high power laser diode arrays (LDAs) that essentially dictate the reliability and lifetime of the solid state laser systems. The most common solid state lasers used for remote sensing applications are Neodymium based 1-micron lasers and the Thulium/Holmium based 2-micron lasers. The 2-micron lasers require a pump wavelength of around 10 to 20 nm shorter compared with 1-micron lasers and pump pulse durations 5 to 10 times longer. This work focuses on the long pulsewidth LDAs operating at a central wavelength of 792 nm used for optically pumping 2-micron solid-state laser materials. Such LDAs are required to operate at moderate to high pulse energies with pulse durations on the order of one millisecond. However, such relatively long pulse durations cause the laser diode active region to experience high peak temperatures and drastic thermal cycling. This extreme localized heating and thermal cycling of the active regions are considered the primary contributing factors for both gradual and catastrophic degradation of LDAs, thus limiting the reliability and lifetime. One method for mitigating this damage is to incorporate materials that can improve thermo-mechanical properties by increasing the rate of heat dissipation and reducing internal stresses due to differences in thermal expansion, thus increasing lifetime. This paper explains the need for long pulsewidth operation, how this affects reliability and lifetime and presents some results from characterization and life testing of these devices.

10:45 AM *FF3.5
Advanced Composites For Lidar Applications. Witold Kowbel and J. C. Withers; MER Corp., Tucson, Arizona.

Improved Lidars systems require significant progress in two areas: laser diodes and optical systems. Thermal management becomes the critical factor in the area of laser diodes. The advanced material such as diamond offers a significant potential but the CTE mismatch with GaAS is the key limitation. In order to address this problem a hybrid carbon-carbon composite/graphite foam heat spreaders were developed. The anisotropy of C-C composites allows for as high as 900 W/mK thermal conductivity. On the other hand properly reprocessed graphite foam allows for very high throgh-the-thickness thermal conductivity. Properly designed submounts were manufactured. The metallization problem was solved by the use of a filtered arc deposition method. The optical components of Lidars impose very stringent requirements on the material selection. Novel forms of SiC-SiC composites were manufactured to address these issues. Due to high fracture toughness greatly increased reliability was achieved. Novel manufacturing processes were developed which allowed for the fabrication of closed-back structures with total elimination of joining. Optical surfaces utilized both Ni and Si. Diamond turning was employed to reduce the optical fabrication cost.

11:15 AM FF3.6
Lightweight and Thermally Stable Optics Materials for Ladar Systems. Anees Ahmad, E-O Subsystems Center, Raytheon Missile Systems, Tucson, Arizona.

The surface quality (figure and micro-roughness) and the wave front error (WFE) of the transmit and receive optics are extremely critical in achieving a high heterodyne mixing efficiency in the range resolved doppler imaging (RRDI) ladars. The optics in such systems must be made from materials, which are not only lightweight but also have high degree of thermal stability under fairly large laser flux. Proper selection of materials for the telescope optics and structure plays a key role in achieving the weight and long-term stability requirements. The telescope fundamental frequency is a key structural parameter that influences the line-of-sight (LOS) jitter during the acquisition and tracking of objects of interest. Deformation of the optics due to laser flux and laser-induced surface damage determines the heterodyne efficiency. In turn, this limits the useful range and resolution of active sensors. Beryllium is the current material of choice for most aerospace sensors due to its light weight and high stiffness. However, it is expensive and toxic. Silicon carbide can be a viable cost-effective alternate material. It offers superior properties such as high stiffness, low density and low thermal expansion. Several commercial companies have developed different grades of silicon carbide material, which are being used to produce large aperture and lightweight optics. These high-performance optical systems have demonstrated the performance and production feasibility of silicon carbide for use in the next generation active sensors. This paper will compare the structural and thermal properties of some viable materials for such applications. The material selection criteria, design, fabrication and test results of high quality optics made from these advanced materials will also be presented.

SESSION FF4/V4: Joint Session: Lasing Materials and Luminescent Devices
Chairs: Astrid Aksnes Dyrseth and Tony Peaker
Wednesday Afternoon, March 30, 2005
Room 3020 (Moscone West)

1:30 PM *FF4.1/V4.1
Rare Earth Ion Implantation for Silicon Based Light Emission: From Infrared to Ultraviolet. Wolfgang Skorupa[1,2], Jiaming Sun[1], Thomas Dekorsy[1], Manfred Helm[1], Lars Rebohle[2], Thoralf Gebel[2], Alexei N. Nazarov[3], Igor P. Tjagulski[3], Igor N. Osiyuk[3], Slawomir Prucnal[4] and Jerzy Zuk[4]; [1]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Rossendorf e.V., Dresden, Germany; [2]Nanoparc GmbH, Dresden, Germany; [3]Institute of Semiconductor Physics, Academy of Sciences of Ukraine, Kiev, Ukraine; [4]Institute of Physics, Maria Curie-Sklodowska-Univ., Lublin, Poland.

Using ion implantation different rare earth luminescent centers (Gd3+, Tb3+, Eu3+, Ce3+, Tm3+, Er3+) were embedded into the silicon dioxide layer of a purpose-designed MOS capacitor with advanced electrical performance. The silicon dioxide layer was produced without silicon nanoclusters. Efficient electroluminescence was obtained from UV to infrared with a transparent top electrode made of indium-tin oxide. Electroluminescence properties were analysed regarding luminescence spectra, decay time, impact excitation cross relaxation, and power efficiency. Top values of the efficiency of 0.2 % corresponding to external quantum efficiencies well above the percent range were reached. The electrical properties of these devices such as carrier injection, charge-to-breakdown, charge trapping characteristics, and operation lifetime for dedicated applications were also evaluated. Although former works showed that for a reliable operation of such devices silicon nanoclusters are needed in the silicon dioxide matrix it will be shown that with the advanced MOS capacitors an increase of the operation lifetimes by a factor of 100-1000 is possible. This allows an analysis of the electro-optical and electrical properties at higher current densities without any degradation problem. The recently demonstrated worldwide first ultraviolet silicon-based light emitter [1] was produced with the here presented device type and will be discussed in more detail. Finally application prospects in the field of biosensing will be shown. [1] J.M. Sun, W. Skorupa, T. Dekorsy, M. Helm, L. Rebohle, T. Gebel, Appl. Phys. Lett. 85, 3387 (2004)

2:00 PM FF4.2/V4.2
Characterization of Er/O-Doped Si-LEDs with Low Thermal Quenching. Amir Karim, Goran Hansson, Wei-Xin Ni and Anders Elfving; Department of Physics and Measurement Technology, Linkoping University, Linkoping, Sweden.

Electroluminescence studies of MBE-grown Er/O-doped Si-diodes at reverse dias have been done. For some devices there is very reduced thermal quenching of the emission at 1.54 μm. there are examples where the temperature dependence is abnormal in that the intensity for a constant current even increases with temperature up to e.g. 80 C. These devices have been studied with cross-sectional transmission electron microscopy to see the microstructure of the Er/O-doped layers as well as the B-doped SiGe-layers that are used as electron emitters during reverse-bias. Although there are defects in the layers there is no evidence for precipitates of SiO2. While reduced thermal quenching often is attributed to having the Er-ions within SiO2 layers or precipitates, this is not the case for our structures as evidenced by our TEM studies. The origin of the abnormal temperature dependence is attributed to the two mechanisms of breakdown in the reverse-biased diodes. At low temperature the breakdown current is mainly due to ionization resulting in low-energy electrons and holes that quenches the intensity by Auger de-excitation of the Er-ions. At higher temperatures the breakdown current is mainly phonon-assisted tunnelling which results in a more efficient pumping with less de-excitation of the Er-ions. Finally at the highest temperatures the thermal quenching sets in corresponding to activation energy of 125 meV, which is slightly lower and thus more favourable than 150 meV that has been reported in other studies.

2:15 PM FF4.3/V4.3
High Efficiency Visible Electroluminescence from Silicon Nanocrystals Embedded in Silicon Nitride. Gun Yong Sung[1], Nae-Man Park[1], Tae-Youb Kim[1], Kyung-Hyun Kim[1], Jaeheon Shin[1], Kwan Sik Cho[2,1] and Jung H. Shin[2]; [1]Future Technology Research Division, ETRI, Daejeon, South Korea; [2]Dept. of Physics, KAIST, Daejeon, South Korea.

Semiconductor electronics is strongly dominated by silicon technology. However silicon technology does not allow easy integration with optical component since silicon is a poor light emitter. There has been much effort to solve the inability of silicon to act as a light emitting source such as porous silicon, erbium doped silicon, and silicon nanocrystals(nc-Si). Among these, nc-Si dispersed in SiO2 matrix has attracted a great interest because their band gap is enlarged in comparison with bulk silicon due to quantum confinement effects. However, it is reported that due to silicon-oxygen double bonds, nc-Si in SiO2 matrix have localized levels in the band gap and emit light only in the near-infrared range of 700~900nm even when the size of nc-Si was controlled to below 2nm. Previously, we reported that red to blue PL were observed from nc-Si quantum dots as well as amorphous Si quantum dots in silicon nitride matrix.[1,2] Therefore nc-Si in silicon nitride matrix supplies the possibility of Si-based full-color emission. We have fabricated light-emitting diodes (LEDs) with a transparent doping layer on silicon nanocrystals (nc-Si) embedded in silicon nitride matrix formed by plasma-enhanced chemical vapor deposition. Under forward biased condition, orange electroluminescence (EL) with its peak wavelength at about 600nm was observed at room-temperature. The peak position of the EL is very similar to that of the photoluminescence (PL) and the emitted EL intensity is proportional to the current density passing through the device. We suggest that the observed EL is originated from electron-hole pair recombination in nc-Si. By using ITO and n-type wide bandgap semiconducting layer combination as a transparent doping layer, we obtained high external quantum efficiency greater than 2.0%, which is the highest value ever reported in nc-Si based LED. [1] Nae-Man Park et al., Phys. Rev. Lett. 86, 1355 (2001). [2] Tae-Youb Kim et al., Appl. Phys. Lett. Nov. 8, 2004 , in press.

2:30 PM FF4.4/V4.4

Study of Optical Gain in Thick GaN Epilayers by Variable Stripe Length Technique. Gintautas Tamulaitis[1], Juras Mickevicius[2], Michael Shur[2], Qhalid Fareed[3] and Remis Gaska[3]; [1]Semiconductor Physics, Vilnius University, Vilnius, Lithuania; [2]Department of ECE and CIE, Rensselaer Polytechnic Institute, Troy, New York; [3]Sensor Electronic Technology, Inc, Columbia, South Carolina.

We report on the gain study in high-quality thick GaN layers grown by Metal Organic Chemical Vapor Deposition (MOCVD) at different conditions using the Variable Stripe Length (VSL) technique. The amplification of light propagating along the layer surface (perpendicular to the c-axis of the crystal) and perpendicular to the layer (along the c-axis) for the layers with thicknesses ranging from 1 to 11 ?m was investigated. Peak gain coefficients of up to 7300 cm-1 in the GaN were estimated by fitting the experimental stripe length dependence of the edge luminescence with one-dimensional description of light amplification in medium with positive gain. Involvement of new gain modes after saturation of the highest-gain modes was observed. GaN samples with different optical gains were also characterized using spontaneous photoluminescence spectroscopy, time-resolved photoluminescence technique, and light-induced transient grating technique that allowed us to determine the nonequilibrium carrier lifetimes. Finally, we discuss the limitations of the VSL technique related to the assumption of one-dimensional light propagation, to the high gain saturation due to the light amplification caused by stimulated transitions at the stripe lengths of several micrometers and consider the influence of heating of the photoexcited electron-hole plasma on the light amplification.

2:45 PM FF4.5/V4.5

Syntheses and Electro-Optical Properties of Twisted Pi-System Chromophores. Hu Kang, Antonio Facchetti, Hua Jiang, Peiwang Zhu and Tobin J. Marks; Chemistry Department and Materials Research Center, Northwestern University, Evanston, Illinois.

A series of nontraditional twisted intramolecular charge-transfer (TICT) chromophores were designed and synthesized. These chromophores exhibit ultra-high hyperpolarizabilities (beta) and optical absorption features strongly dependent on the interplanar dihedral angle. The tunable structural characteristic that promotes these optical/nonlinear optical features/responses is a sterochemically enforced reduction of the D-A Pi-conjugation that enforces zwitterionic behavior in the ground state and provides a low-energy and large-oscillator strength intramolecular excitation feature. The consequence is that molecules with a relatively small number of Pi-electrons exhibit responses far larger than those of corresponding traditional planar Pi-conjugated chromophores.Evaluations of electro-optic devices based on these chromophores are in progress.

SESSION FF5/V5: Joint In-Room Poster Session:
Lasing Materials and Luminescent Devices
Chairs: Astrid Aksnes Dyrseth and Tony Peaker
Wednesday Afternoon, March 30, 2005
3:30 PM - 5:00 PM
Room 3020 (Moscone West)

FF5.1/V5.1

Influence of Rapid Thermal Annealing on Self-Assembled Quantum-Dot Superluminescent Diodes. Ziyang Zhang[1], Ying Yin Tsui[1], Robert Fedosejevs[1] and Zhanguo Wang[2]; [1]University of Alberta, Department of Electrical & Computer Engineering, Edmonton, Alberta, Canada; [2]Key Laboratory of Semiconductor Materials Science, Institute of Semiconductors, Chinese Academy of Sciences, Beijing, China.

Superluminescent diodes (SLD) have great potential for application as light sources including optical gyroscopes and sensors, optical time domain reflectometers (OTDR) and wavelength-division multiplexing (WDM) system testing. High output power and large spectral bandwidth are key features for SLD. In recent years, self-assembled quantum dots (SAQD) instead of quantum well have attracted significant attention for laser diodes (LD) application. QD-LD are expected to attain high power, less temperature-sensitive operation, and a remarkable reduction in threshold current, due to the discrete atom-like states in QD. Much of the interest in QD-LD focuses on the uniform growth of QD's to obtain sufficient gain to lase. However, it is noted that non-uniform characteristics of QD size can be beneficial to SLD to realize the desired wide spectral bandwidth. In this work, two kinds of SAQD-SLDs have been fabricated. Both of them were with tilted-stripe active region. The only difference between them was one has been treated with rapid thermal annealing (RTA) while the other has not. Continuous wave (CW) output power of 200mW and a spectral width of 60nm were realized at room temperature by the sample which has not been treated with RTA. In addition, the CW output power of 200mW was obtained at only 1.4A injection current. As a SLD, it was a very high efficiency. However the CW Maximal output power was only 140mW and the spectral width was 40nm of the sample which has been treated with RTA. As we know, the homogeneity of quantum dots can be effectively improved after RTA, and it will generally be beneficial for QD-LD. However, in this case, for QD-SLD, the RTA effect was quite different from that of QD-LD. It indicated that the appropriate inhomogeneity of QD is an important factor to realize high performance Superluminescent diodes. One of the authors (Ziyang Zhang) would like to acknowledge finacial support from the Alberta Ingentuiy Fund.

FF5.2/V5.2

A Novel Class of Imidazole-Containing Excited-State Intramolecular Proton Transfer Materials: Synthesis and Amplified Spontaneous Emission from a Single Crystal. Sanghyuk Park[1], Sehoon Kim[1], Oh-hoon Kwon[2], Du-Jeon Jang[2], Sangwoo Park[3], Moon-Gun Choi[3] and Soo Young Park[1]; [1]Materials Science and Engineering, Seoul National University, Seoul, South Korea; [2]School of Chemistry, Seoul National University, Seoul, South Korea; [3]Department of Chemistry, Graduate School, Yonsei University, Seoul, South Korea.

The excited-state intramolecular proton transfer (ESIPT) reactions have been intensively investigated because of the fundamental importance of this process and its potential for practical applications in laser dyes, solar energy concentrators, chemosensors, and electroluminescent materials. To realize a compact and rugged device with better performance, most of the ESIPT applications demand a highly concentrated solid state system. However, it normally happens that the intermolecular interactions in the condensed system raise the problem of significant concentration quenching in the fluorescence intensity, which is an important challenge in the fluorescent ESIPT materials as well. Very recently, we reported highly concentrated but still ESIPT-active solid materials by introducing dendrimer structures, and we have been successful in demonstrating that the fluorescence emission can be greatly enhanced in the aggregated system when the molecular structure is properly designed. As a continued effort in these works, we have designed and synthesized a novel class of ESIPT materials, hydroxy-substituted tetraphenyl imidazole (HPI) and its derivative HPI-Ac, which assumes aggregation-induced enhanced emission (AIEE) in the solid state. Prepared materials showed transparent and well-formed single crystals with intense blue photoluminescence and amplified spontaneous emission (ASE). The structural characteristics of HPI and HPI-Ac were fully identified by X-ray crystallography. The crystal structures were triclinic and the two phenyl rings at 1- and 5-positions of central imidazole ring are twisted almost perpendicular to the chromophore plane. These two twisted phenyl rings appropriately prevent direct stacking of the active chromophores in a zig-zag manner and maintain proper intermolecular distance, and reduce the concentration quenching of ESIPT fluorescence. The ESIPT kinetics and proton-transfer ASE were studied by an actively/passively mode-locked Nd:YAG laser (Quantel, YG701) and a 10-ps streak camera (Hamamatsu, C2830) attached to a CCD detector (Princeton Instruments, RTE128H). The intrinsic four-level nature of ESIPT contributes to easy population inversion, and the low-threshold ASE from HPI-Ac will be discussed in this work.

FF5.3/V5.3

Organic/Inorganic Hybrid Glasses Doped with (Erbium-ions/CdSe nanoparticles) for Laser Amplifiers.
Kyung M. Choi, [1]Bell Labs, Lucent Technologies, Murray Hill, New Jersey; [2]Department of Materials Science and Engineering, University of Illinios at Urbana-Champaign, Urbana, Illinois.

A new family of organic/inorganic hybrid silicate materials, bridged polysilsesquioxanes, was designed and synthesized through a molecular-level mixing technique. By modifying the Si-O-Si polymeric network, we produced controllable, porous glass materials for facile and uniform doping of various ions, metals or semiconductor particles. By taking advantage of void volume created in those molecularly modified silicate systems, we developed hexylene- or fluoroalkylene-bridged polysilsesquioxane doped with both Er+3 ions and CdSe nanoparticles for the development of new laser amplifier materials. In photoluminescent experiments, a significant enhancement in fluorescent intensity at 1540 nm has been obtained from the fluoroalkylene-bridged glass. Analysis by nuclear magnetic resonance indicates a dramatically enhanced degree of condensation and a low level of hydroxyl environment in the fluoroalkylene-bridged glass matrix. The presence of CdSe nano-particles, by virtue of their low phonon energy, also appears to significantly influence the nature of the surrounding environment of Er+3 ions in those modified silicate systems, resulting in the increased fluorescent intensity.

FF5.4/V5.4

PL Excitation Mechanism of Eu and Pr doped GaN Grown by Hydrate Vapor Phase Epitaxy on Sapphire.
Wojciech M. Jadwisienczak[1], Henryk J. Lozykowski[1] and Richard J. Molnar[2]; [1]School of EECS, Ohio University, Athens, Ohio; [2]Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Massachusetts.

We report measurements of the photoluminescence excitation (PLE) spectra, time resolved spectra and kinetics using tunable Sunlight laser system for Eu and Pr doped GaN. Investigated samples grown by hydrate vapor phase epitaxy were implanted with different rare earth ions doses and thermally treated at 1100 C in NH3 and N2 to remove ion implantation-induced damages, and make RE impurities optically active. From PLE experiments we have founded that the defect level near conduction band of GaN Eu doped samples are involved in an energy transfer to 4f electrons of Eu3+ ion. On the basis of experimental results the possible excitation mechanisms for RE3+ ions are briefly discussed.

FF5.5/V5.5

Fabrication of Er3+/Pr3+ Co-Doped Soda Lime Glass Thin Films Using RF Magnetron Sputter and Optical Property Characterization. Sang Hoon Shin, Ki Young Yoo, Dong-ryul Jung, Jong Ha Moon and Jin Hyeok Kim; Department of Materials Science & Engineering, Chonnam National University, Gwangju, South Korea.

Er3+/Pr3+ co-doped soda lime glass thin films have been fabricated using RF magnetron sputtering method and their structural and optical properties have been studied. Deposition rate, crystallinity, and composition of glass thin films were investigated by scanning electron microscopy, transmission electron microscopy, and electron probe micro area analysis. Refractive index, birefringence, and binding characteristics between atoms have been investigated using a prism coupler and x-ray photoelectron spectroscopy. Er3+/Pr3+ co-doped soda lime glass thin films were prepared by changing substrate temperature (room temperature - 550°C), RF power (90W -150W), and Ar/O2 gas flow ratio at processing pressure of 4mTorr. The deposition rate depends on the processing parameters. It increased as the RF power increased and decreased as the Ar/O2 gas flow ratio increased. Especially, a high quality glass thin films that have similar composition with the compositions of the targets were obtained at 350°C, RF power of 130W, and gas flow ratio of Ar:O2 (40:0) with maximum deposition rate of 1.6μm/hour. Refractive index increased from 1.5614 to 1.5838 and birefringence increased from 0.000154 to 0.000552 as the content of Pr increased. Binding energy of rare earth ions increased as the content of Pr increased.

FF5.6/V5.6

A Novel Approach to Achieve Broadband Luminescence from Tm^{3+} and Er^{3+} Codoped Al_2O_3 Thin Films. Zhisong Xiao[1], Rosalia Serna[1], Carmen N. Afonso[1] and Ian Vickridge[2]; [1]Instituto de Optica, CSIC, Madrid, Spain; [2]Groupe de Physique des Solides, Universite de Paris 6 et 7, Paris, France.

Integrated optoelectronic circuits require the development of light sources and optical amplifiers in planar waveguides. Rare earth (RE) doping of dielectrics allows preparing suitable materials for these applications. Moreover, there is a great effort to develop devices for wavelength-division-multiplexing (WDM) in local network systems, and induces a demand for optical amplifiers utilized near 1.4 μm and 1.6 μm, in addition to the present silica-based erbium (Er) doped amplifiers (1530-1600 nm). Thus it is interesting to explore the possibility of profiting from emission of more than one kind of RE ion in a single integrated device. Tm^{3+} is promising as a complement to Er^{3+} (emission at 1.54 μm) due to its emission bands around 1.47 μm and 1.6-1.8 μm. In particular recently work we have found in Tm^{3+} doped Al_2O_3 two efficient emission bands peaked at 1.48 μm and 1.64 μm. The aim of this work is to achieve the broadband luminescence by codoping thin films with Er^{3+} and Tm^{3+} and controlling both concentration and dopant distribution in the nanoscale. The amorphous aluminum oxide (Al_2O_3) thin films codoped with Er^{3+} and Tm^{3+} have successfully been prepared by pulsed laser deposition (PLD). The number of Tm-Tm layers between two Er layers separated 6 nm has been designed to be 1, 2, and 5 corresponding to the film with Tm^{3+}-Tm^{3+} layer in-depth separation of 3, 2 and 1 nm, and an areal density of Tm^{3+} in the range of 2.15×10^{15} - 1.07×10^{16} cm^{-2} is determined by the RBS analyses. Er^{3+} areal density is $\sim 2.15\times10^{15}$ cm^{-2} for all Er-Tm doped films. When pumping with 794 nm light from a Ti: sapphire laser a broad photoluminescence (PL) band with a full-width half maximum (FWHM) up to 250 nm was observed. This broad PL band is the result of the convolution of simultaneous luminescence of both Er^{3+} and Tm^{3+}. By the addition of Tm^{3+} the typical Er^{3+} spectrum in Al_2O_3 peaked at 1540 nm (FWHM $\sim$ 60 nm) was modified by an enhancement of the PL intensity in the region of 1400-1500 nm and the appearance of a broad shoulder peaked at 1640 nm. The evolution of the broad band spectra was studied as a function of the Tm^{3+}/Er^{3+} concentration ratio. As the concentration ratio increases both the PL intensity and lifetime of 1640 nm peak increase, and in the meantime both the PL intensity and lifetime of 1540 nm peak decrease. It is shown that this is the consequence of energy transfer between the transition of Er^{3+}: $^4I_{13/2}$ - $^4I_{15/2}$ and Tm^{3+}: $^3F_4$ - $^3H_6$. It will be shown how by adjusting the Tm content and Tm-Tm separation between two Er layers can be used to tailor 1.4-1.7 μm PL response of Er-Tm codoped Al_2O_3 films for broadband application.

FF5.7/V5.7

The Impact of Deposition Parameters on Optical and Compositional Properties of Er Doped SRSO Thin Films Deposited by ECR-PECVD. Michael Flynn[1,2], Jacek Wojcik[1,2], Edward Irving[1,2] and Peter Mascher[1,2]; [1]Engineering Physics, McMaster University, Hamilton, Ontario, Canada; [2]Centre for Electrophotonic Matrials and Devices, Hamilton, Ontario, Canada.

Silicon rich silicon oxide (SRSO) thin films have been deposited, with in-situ Er doping via an organometallic precursor, using electron cyclotron resonance plasma enhanced chemical vapor deposition (ECR-PECVD). The films had thicknesses of approximately 1000 ? and silicon concentrations ranging from 33 to 45 %. Using heavy ion elastic recoil detection, it was found that the SRSO composition, specifically the silicon to oxygen ratio, was significantly impacted by the erbium incorporation. It was also determined that varying the microwave power affects the incorporation of erbium during the thin film deposition process. Additionally, ellipsometry has been used to characterize the effects of microwave power and film composition on the optical properties of the films. Results from Fourier transform infra-red absorption measurements of these films will be discussed in relation to the composition and optical measurements and with reference to the broader field of silicon based photonics. This work is being supported by Ontario Centres of Excellence (OCE) Inc. and the Ontario Photonics Consortium (OPC).

FF5.8/V5.8

Luminescence of Rare Earth Doped Si/ZrO_2 Co-Sputtered Films. Carlos Rozo Rozo, Luis Fonseca, Oscar Resto and Zvi Weisz; Physics, University of Puerto Rico at Rio Piedras, San Juan, Puerto Rico.

Er^{3+}, Nd_{3+} and Tm_{3+} doped Si/ZrO_2 thin films have been prepared by rf co-sputtering. The films are 5 inches long and divided into 50 sections or positions, labeled from P1 to P50. The target configuration is such that the main target is ZrO_2 (182.14 cm^2), the rare earth (RE) oxide pellet (1.4 cm^2) is placed on the main target below the middle of section of the film and the Si chip (6.67 cm^2) is placed on the main target below one end of the film (P40 to P50). The films were annealed to 700°C. The Er^{3+} $^4I_{13/2} \rightarrow {}^4I_{15/2}$ emission was detected but unlike similar Er-doped Si/SiO_2 and Er-doped Si/Al_2O_3 films no $^4I_{11/2} \rightarrow {}^4I_{15/2}$ emission was detected. The $^4I_{13/2} \rightarrow {}^4I_{15/2}$ emission shows a much narrower peak at 1527 nm (FWHM $\approx$ 7nm for P20) with two weaker side bands from 1430 nm to 1500 nm and from 1550 nm to 1600 nm. The Nd^{3+} $^4F_{3/2} \rightarrow {}^4I_{9/2}$, $^4F_{3/2} \rightarrow {}^4I_{11/2}$, and $^4F_{3/2} \rightarrow {}^4I_{13/2}$ emissions were detected being the $^4F_{3/2} \rightarrow {}^4I_{11/2}$ peaked at 1065 nm (FWHM $\approx$ 40 nm for P30) the strongest. The $^4F_{3/2} \rightarrow {}^4I_{9/2}$ emission is relatively weak, less than one-fourth the peak intensity of the $^4F_{3/2} \rightarrow {}^4I_{11/2}$ emission but is broad (FWHM $\approx$ 80 nm for P30). Compared to similar Nd-doped Si/SiO_2 and Nd-doped Si/Al_2O_3 films the $^4F_{3/2} \rightarrow {}^4I_{13/2}$ is stronger, peaked at 1324 nm and extending from 1280 nm to 1380 nm. No Er^{3+} $^4I_{13/2} \rightarrow {}^4I_{15/2}$ emission or Nd^{3+} $^4F_{3/2}$ emissions were detected for the Si rich ends of the respective films, being the emission stronger from the Si poor end of the film towards the middle of the film. The maximum Er^{3+} $^4I_{13/2} \rightarrow {}^4I_{15/2}$ emission is for P20 and the maximum peak intensity for the Nd^{3+} $^4F_{3/2} \rightarrow {}^4I_{11/2}$ emission is for P30. The excitation wavelength dependence behavior for the Nd^{3+} $^4F_{3/2} \rightarrow {}^4I_{11/2}$ emission is that typical of energy transfer from the Si nanoparticles to the emitting Nd^{3+} ions. The excitation wavelength behavior for the Er^{3+} $^4I_{13/2} \rightarrow {}^4I_{15/2}$ emission reflects a mix of energy transfer from the Si nanoparticles and strong resonant absorption for excitation wavelengths of 488.0 nm and 514.5 nm. The Tm^{3+} doped Si/ZrO_2 thin film does not exhibit infrared (IR) PL from the $^3H_4 \rightarrow {}^3F_4$ emission or the $^3F_4 \rightarrow {}^3H_6$ emission. The intense band from 500 nm to 800 nm observed for all of the RE doped Si/ZrO_2 films, due to defects in ZrO_2, barely permits the detection of the Tm^{3+} $^3H_4 \rightarrow {}^3I_6$ emission which is best observed for P35.

FF: Special Topics
Wednesday March 30, 2005
1:30 PM - 4:00 PM
Room 2009 (Moscone West)

Special Presentation: Reliabity of Laser Diode Pump Arrays in Space-based Lidars.

Lecturer:
Henning Leidecker

2:30 PM BREAK

Wednesday, March 30, 2005
Room 3020
3:00 PM - 4:00 PM

Panel Discussion: Role of New Photonic Devices and Fiber Optics Lasers in Advancing Laser Remote Sensing.

Moderators:
Nasser Peyghambarian
Farzin Amzajerdian

SESSION FF6: Advanced Lidar Receivers and Detectors
Chairs: Astrid Aksnes Dyrseth and Peter Moulton
Thursday Morning, March 31, 2005
Room 3020 (Moscone West)

8:30 AM *FF6.1
Laser Radar Systems using Arrays of Geiger-mode Avalanche Photodiodes. Richard M. Heinrichs, M.I.T. Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Massachusetts.

M.I.T. Lincoln Laboratory is developing arrays of avalanche photodiodes for use in 3-dimensional (3-D) imaging laser radars. These hybrid devices consist of an array of Geiger-mode avalanche photodiodes (APDs) bonded to commensurate timing circuitry. Geiger-mode operation offers the combined advantages of single-photon sensitivity, less sensitivity to material variations across the array, and relative simplicity in the timing circuitry, which simply records the time that the APD fires. These arrays have been fabricated in a 32 x 32 format with silicon detectors, for visible detection, InGaAsP detectors for detection near 1 micron and InGaAs detectors for detection near 1.5 microns. The detector arrays have been incorporated into laser radar systems that have demonstrated the utility of photon-counting 3-D imaging for target shape determination, wide-area mapping, and obscurant penetration. This paper will present an update of the technology development at Lincoln Laboratory for 3-D imaging laser radar. The basic detector and laser technologies will be discussed along with examples of integrated laser radar systems and their performance.

9:00 AM FF6.2
Near-infrared Photodetection using Molecular Beam Epitaxy Grown Extended InGaAs. Junxian Fu[2,1], Xiaojun Yu[1], Yu-Hsuan Kuo[1], Vince Lordi[1] and James S. Harris[1]; [1]Solid State and Photonics Lab, Stanford University, Stanford, California; [2]Applied Physics, Stanford University, Stanford, California.

The near-infrared wavelength range is of extensive interest for hyperspectral sensing, laser radar, environment gas monitoring and next-generation optical communications. Lattice-matched InP/InGaAsP based materials have provided the foundation for state-of-the-art optical communications devices. Standard lattice-matched InGaAs to InP has 53.2% indium and covers the wavelength range up to 1.7μm, while extended InGaAs (with indium composition more than 53.2%) can extend the wavelength range to 1.8-2.5μm, a region of far more spectral interest for remote sensing. A stain-balanced growth technique was applied in the molecular beam epitaxy growth of extended InGaAs on InP substrates. Ten periods of tensile strained (In $<$ 0.532) and compressive strained (In $>$ 0.532) InGaAs were successfully grown. Both layers have 0.8% strain to InP and each have layer thicknesses of 20nm in each period, which is well within the critical thickness calculated from the theoretical models. Controlled strain-balance In0.67Ga0.33As/In0.41Ga0.59As superlattices show an absorption edge at 1.96μm and room-temperature photoluminescence peak at 1.94μm. The absorption coefficient was estimated to be 2.4$\times$10$\hat{3}$cm-1 at 1.9μm. In order to push the sensitive wavelength further into the infrared, a fractional monolayer super-lattice of InAs/InGaAs was grown as a quantum well layer with standard InGaAs cladding layers. Single quantum well and multiple quantum well structures were grown and characterized. The MBE growth was monitored and optimized by in-situ reflective high-energy electron diffraction, ex-situ high resolution X-ray diffraction, room temperature photoluminescence and optical absorption measurements. The quantum well thickness was controlled to assure coherent growth of all layers. Room-temperature photoluminescence measurements showed an emission peak at 2.2μm. TEM pictures reveal quantum well thickness fluctuations resulting in the broad photoluminescence peak. Dark current properties of photodiodes and hetero-junction phototransistors were analyzed and the materials grown here show lower dark currents than metamorphic grown high indium concentration InGaAs on InP or GaAs. Spectral responsivity was measured from 1.4 to 2.5μm. A standing wave Fourier transform interferometer was demonstrated using a partly transparent detector and PZT controlled scan mirror. With a travel length up to 38μm, we can get spectral resolution of 17nm at 2μm. Details of the superlattice growth, characterization and spectrometer performance will be described.

9:15 AM FF6.3
A Novel Direct Detection Doppler Lidar Receiver for Tropospheric Wind Profiling. Bruce M. Gentry, Brent Bos, Caner Cooperider and Stan Scott; Laboratory for Atmospheres, NASA Goddard, Greenbelt, Maryland.

Global tropopsheric wind profiling is an important objective for the research and operational atmospheric science communities. We have previously developed and demonstrated a capability to profile winds from the ground to altitudes of 40 km using a molecular backscatter direct detection Doppler wind lidar. The Doppler measurement is done with a receiver based on the double edge technique. We have recently completed the design of a second generation molecular double edge receiver. This receiver occupies only 10% of the volume of the current system. In addition to being more compact, the receiver has higher throughput and much larger signal dynamic range. The new Doppler receiver will be described including implications for future air and space based lidar instruments.

9:30 AM *FF6.4
Acoustic Sensing with Optics. Berit Sundby Avset, Kari A. H. Bakke, Britta Grennberg Fismen, Ib Rune Johansen, Henrik Rogne, Haakon Sagberg and Dag T. Wang; SINTEF ICT, Oslo, Norway.

Two different micro-optical microphones are presented. The first is based on interferometric read-out of a deflecting membrane, based on the Fabry-Perot principle. The sensing device is produced in Silicon by combining standard CMOS and MEMS processing. This ensures that high accuracy alignment and low cost production can be obtained. Optical sensor elements with a ring structure are included on one of the Fabry-Perot surfaces whereas the other surface is an optically transparent membrane. Light from an uncollimated light source such as a semiconductor laser or a LED, will from a ring pattern described by the Airy function when transmitted through the membrane. The other microphone principle presented is based on a diffractive lens. The structure has a metallic ring pattern separated from a reflecting membrane with an air gap. When the air gap is an odd number of quarter wavelengths of the impinging light, these surfaces form a binary phase diffractive lens. By placing a light source and a detector in the focal plane of the lens, the measured intensity will be highly sensitive to the position of the membrane. Similarly to the first microphone this device can also be mass produced at low cost using micromachining techniques. Results from prototype devices will be presented, proving both principles and showing excellent properties compared to expensive commercially available condenser microphones.

10:00 AM FF6.5
Whispering Gallery Mode Filters for LIDAR Applications.
Andrey B. Matsko, Lute Maleki, Anatoliy A. Savchenkov and Vladimir S. Ilchenko; MS 298-100, Jet Propulsion Laboratory, Pasadena, California.

We discuss the application of an optical filter based on coupled whispering gallery mode (WGM) resonators in LIDAR systems. The filter is characterized with low-loss, high-rejection, and narrow optical bandpass, and is tunable across the entire visible and infrared optical range, with electro-optic effect. The insertion loss of the prototype filters that we have already demonstrated is a about 4 dB. Their optical bandwidth can be tailored within a 10 kHz - 10 MHz range. The demonstrated signal rejection outside of the pass band is 60 dB, and we expect to make it even higher in the deliverable implementation of the instrument. WGM optical microcavities are small dielectric resonators that support extremely high Q-factor modes. These modes propagate close to the surface of the resonator, and their quality factors are determined by three parameters: intrinsic material loss, bending loss, and scattering loss. In the past, microspherical resonators with dimensions in the range of 50 to 500 microns have been fabricated from fused silica with quality factors as high as a few billion. We have recognized that high Q microresonators can also be produced with crystalline materials. This is an enormous extension of the microresonators capabilities, since crystalline material can lead to even higher quality factors, and their intrinsic properties such as electro-optical effect can be put to advantage in realization of new functionalities, such as filtering. One of the materials we used in fabricating microresonator is lithium niobate, which has a large electro-optic coefficient. A lithium niobate resonator is immune to atmospheric conditions; unlike e.g. resonators made with fused silica, which looses its quality-factor in air. The geometrical size of the resonator-based filter including input and output optics is the size of a dime with a mass of less than ten grams. A single disk microresonator has a dense optical spectrum, and each of its lines has a Lorentzian shape. Both these factors limit the application of such microresonatos as filters. However, if several microresonators are cascaded, the coupled structure creates a multi-pole filter with a steep and single-peak transmission function. Such a filter can be enormously useful for LIDAR applications because it will increase the spectral resolution of the LIDAR spectrometers by four to five orders of magnitude as compared with existing ones. Moreover, the use of WGM resonator technology will allow for a design of the instruments surpassing the state-of-the-art in terms of small size, low power consumption, and low weight. The LIDAR based on this technology will operate at any wavelength in the transmission window of the crystals the filter is made of (e.g. from 400 nm to 3000 nm for lithium niobate, and from 150 nm to 10000 nm for calcium fluoride).

SESSION FF7: Future of Laser Remote Sensing and Applications I
Chairs: Richard Heinrichs and Christopher Moore
Thursday Morning, March 31, 2005
Room 3020 (Moscone West)

10:30 AM *FF7.1
Technologies for Earth and Planetary Remote Sensing.
Upendra Nath Singh, Systems Engineering Directorate, NASA Langley Research Center, Hampton, Virginia.

In 2002 the NASA Earth Science Enterprise (ESE) and Office of Aerospace Technology (OAT) created the Laser Risk Reduction Program (LRRP) in FY02 in response to 1) concerns about the risk of space-based lidar missions, 2) the November 2000 report of an Independent Laser Review Panel, and 3) the June 2001 recommendations of the Integrated NASA Lidar Systems Strategy Team (INLSST). The goal of this program is to develop enabling technologies for space-based measurements of a variety of Earth science measurements including: atmospheric chemistry, water vapor, aerosols and clouds, wind speed and direction, pollution, oceanic mixed layer depth, land-locked ice, sea ice, vegetation canopy and crop status, biomass, vegetative stress indicator, surface topography, and others. The technologies under development also have numerous applications for other NASA Enterprises, such as aeronautics, space science (planetary atmospheric measurements, surface mapping and spacecraft landing and rendezvous), and homeland defense. This paper gives the overview of the NASA's Laser Risk Reduction Program (LRRP) and describes the progress made at NASA Langley Research Center towards advancing the laser technologies for space-based remote sensing of the earth and planetary atmosphere.

11:00 AM *FF7.2
Aladin: The First European Lidar in Space. Didier Morancais and Fabre Frederic; EADS Astrium, Toulouse Cedex, France.

The Atmospheric LAser Doppler INstrument (ALADIN) is the payload of the ADM-AEOLUS mission, which aims at measuring wind profiles as required by the climatology and meteorology users. ALADIN belongs to a new class of Earth Observation payloads and will be the first European Lidar in space. The instrument comprises a diode-pumped high energy Nd:YAG laser and a direct detection receiver operating on aerosol and molecular backscatter signals in parallel. In addition to the Proto-Flight Model (PFM), two instrument models are developed: a Pre-Development Model (PDM) and an Opto-Structure-Thermal Model (OSTM). The flight instrument design and the industrial team has been finalised and the major equipment are now under development. This paper describes the instrument design and performance as well as the development and verification approach. The ALADIN instrument is developed under prime contractorship from EADS Astrium SAS with a consortium of thirty European companies.

11:30 AM *FF7.3
Multi-Discriminant Laser Sensing for Combat Identification.
Bryce Schumm and Paul McManamon; Electro-Optics Combat Identification, AFRL/SNJM Air Force Research Lab, Wright-Patterson AFB, Ohio.

Positive identification of enemy forces continues to be a major problem. In Kosovo our adversary employed advanced, yet inexpensive, deception and camouflage techniques. In Iraq we're presented with finding important targets in an urban environment - an area with a very high clutter to target mix. To be able to effectively sort the wheat from the chaff requires a multi-discriminant sensing approach to combat identification. By sensing multiple EO discriminants (for example shape, vibration, polarization, and effluents) CC&D techniques can be more effectively countered. Over the past several years, AFRL has been developing laser sensors that look at a single discriminant. New programs are bringing those together to sense multiple object attributes simultaneously. Furthermore, advanced techniques, such as synthetic aperture processing, which exploit many of the lessons learned from the RF world as well as utilizing the inherent carrier bandwidths available with laser radars are being brought to bear to provide unambiguous combat identification. This paper will explore many of the on-going programs at AFRL that seek to integrate multi-thread systems into an integrated package. Further discussion will center around advanced programs looking to take a revolutionary approach to laser sensing.

SESSION FF8: Future of Laser Remote Sensing and Applications II
Chairs: Farzin Amzajerdian and Lhadi Merhari
Thursday Afternoon, March 31, 2005
Room 3020 (Moscone West)

1:30 PM *FF8.1
Advanced Laser Technology for Exploration Missions.
Christopher Moore, Advanced Space Technology Program, Exploration Systems Mission Directorate, NASA, Washington DC, District of Columbia.

NASA's Advanced Space Technology Program is developing high-performance laser materials and devices for future exploration missions. Laser technology is needed for robotic vision systems, automated rendezvous and docking, atmospheric profiling, and planetary mapping. An overview of current research projects will be presented.

2:00 PM *FF8.2
Lidar Remote Sensing Applications: Ready and Waiting.
John F. Hahn, Space and Atmospheric Division, Optech Incorporated, Toronto, Ontario, Canada.

Lidar (Light Detection And Ranging) is used in a variety applications, spanning fields as diverse as atmospheric remote sensing, topographical mapping and remote structural analysis. Atmospheric remote sensing applications for lidar include determination of the distribution of atmospheric scatterers, retrieval of concentration profiles for atmospheric chemical species and evaluation of phase state of suspended atmospheric aerosols. The lidar technique has also been used to precisely retrieve hard-target range data, such as provided by ground returns used subsequently in topographical and bathymetric mapping or hard-target signal returns from buildings and structures as needed for engineering assessment. There are many differences between these techniques so far as the details of operation are concerned. However, the connecting thread between all of the cases mentioned is the range information derived from collected photon time-of-flight data. These data are of spatial fidelity and resolution that often surpass the capabilities of other remote sensing techniques, making lidar the technology of choice for a growing number of uses. Lidar technology is itself dependent upon a number of relatively new tributary technologies, many of which are still the focus of intensive development efforts, e.g. lasers, lightweight optics, detector and electronics. Moreover, lidar deployment itself has become ever more ambitious, to the point that spaceborne lidar instruments have already successfully participated in Terrestrial, Lunar and Martian observation missions with many new missions, of varying scope and complexity, planned for the future. The success of future applications will depend upon a well-balanced trade of capability from each of constituent technologies. In this presentation, lidar applications, ready and waiting, will be discussed. "Ready" applications, that is lidar systems already operating and serving the needs of communities in atmospheric, earth and planetary sciences, include airborne terrain mapping (ALTM), airborne bathymetric mapping (SHOALS), ground-based imaging rangefinding (ILRIS) and ceilometry (AirDrop). "Ready" spaceborne applications include orbital rendezvous and docking (XSS-11, HRV), precision landing/hazard avoidance (Mars Smartlander) and Martian atmospheric evaluation (PHOENIX). "Waiting" systems, on the other hand, include those lidar instruments under development, planned or studied and for which development paths have been defined. These include spaceborne differential absorption lidar (DIAL) for the measurement of important trace species such as ozone and water vapor in the Earth's atmosphere (ORACLE, WALES) and imaging rangefinders for planetary topographical mapping. Each of these systems presents its own challenges and critical technical issues. An evaluation of some of the issues facing further lidar development and application directions will be presented.

2:30 PM FF8.3
Lidar Technology Role in Future Robotic and Manned Missions to Solar System Bodies. Rosemary R. Baize, Farzin Amzajerdian, John Davidson, Richard W. Powell and Frank Peri; NASA Langley Research Center, Hampton, Virginia.

Future planetary exploration missions will require safe and precision soft-landing to target scientifically interesting sites near hazardous terrain features, such as escarpments, craters, slopes, and rocks. Although the landing accuracy has steadily improved over time to approximately 35 km for the recent Mars Exploration Rovers due to better approach navigation, a drastically different guidance, navigation and control concept is required to meet future mission requirements. For example, future rovers will require better than 6 km landing accuracy for Mars and better than 1 km for the Moon plus 100 m maneuvering capability to avoid hazards. Laser Radar or Lidar technology can be key to meeting these objectives since it can provide high-resolution 3-D maps of the terrain, accurately measure ground proximity and velocity, and determine atmospheric pressure and wind velocity. These lidar capabilities can enable the landers of the future to identify the pre-selected landing zone and hazardous terrain features within it, determine the optimum flight path, having atmospheric pressure and winds data, and accurately navigate using precision ground proximity and velocity data. This paper examines the potential of lidar technology in future manned and robotic missions to the Moon, Mars, and other planetary bodies. A guidance and navigation control architecture concept utilizing lidar sensors will be presented and its operation will be described. The performance and physical requirements of the lidar sensors will be also discussed.

2:45 PM FF8.4
Laser Radar Needs. Douglas Bruce Langille, BAE Systems, Huntsville, Alabama.

Various needs pertaining to laser radars have been observed. This paper indicates areas for performing basic research to discover new materials/devices/techniques to address these needs in future systems. There is a need for high-power high-repetition rate illumination lasers that operate in the eye safe region. Existing lasers that operate at eye safe wavelengths do not have the high-power, high-repetition rate capability; lasers that approach the high power/repetition levels, require use of crystals, that are subject to fracture, to convert the initial wavelength to an eye safe wavelength. Basic research to identify/develop a material that has an emitting transition at an eye safe wavelength and could, in combination with other laser components, have high power and high repetition rates is needed. Although not specifically for a laser radar, but along the development lines of determining new eye safe laser material, is the need to identify/develop a novel material that could produce high energy laser pulses, and when incorporated with other laser components provide a compact high-energy laser. Capability to detect/image targets at longer ranges is needed. Identification/development of a new detector material that would have a high quantum efficiency/detectivity to provide capability to respond to lower levels of returning photon intensities is needed. Capability to determine total laser radar cross section using avalanche photodiodes is needed. Laser radars using avalanche photodiode detectors can obtain excellent angle-angle and range Doppler images. However, due to the avalanche photodiode process of saturating after incidence of one photon, the usual method of determining laser radar cross sections by determining the intensity from multiple photons at detector elements cannot be performed. A novel technique/algorithm to determine the total laser radar cross section from the avalanche photodiode responses is needed.