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13. ABSTRACT (Maximum 200 words)

The DURIP '99 initiative award was used primarily for a major upgrade of a dual rack ONYX2 Silicon Graphics system. The upgrade consisted in purchasing 8 of the newest generation of 400 MHz CPU's, converting one of ONYX2 racks into a fully loaded 16-processor Origin 2000/2400 system and moving both high performance graphics heads into the top half of the remaining ONYX2 rack. The existing 14 processor system consisted of a mix of 6 195MHz and 8 250 MHz CPUs running in a system with 6 Gbytes of memory. In addition, Silicon graphics replaced our existing mix of 14 195 and 250 MHz CPUs by 14 300 MHz CPUs at no added cost. The new system provides a state-of-the-art graphical visualization and computing capability. It also offers a cost-effective upgrade route. The reconfigured in-house supercomputing engine provides a significant boost to our past and ongoing AFOSR-funded research projects. The new system supports the current contracts, "Semiconductor Amplifiers and Laser Wavelengths from Microscopic Physics to Device Simulation" (AFOSR 49620-00-1-0002), and AASERT grants, "High Power Femtosecond Laser Light Strings", (AFOSR F49620-00-1-0312); and "Interactive Nonlinear PDE Simulators", (AFOSR F49620-97-1-0451).

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Interactive and Large Scale Supercomputing Simulations in Nonlinear Optics The significantly increased computing capacity resulting from the DURIP award has enabled us to tackle the following major problems. Novel nitrogen-doped GaAs and InGaAs materials lasing at Telecoms Wavelengths. Our contract research is driven by large scale computation in nonlinear optics areas of direct interest to Air Force Laboratory scientists. Interactions and collaborations exist with Air Force scientists at the Air Force Research Laboratory (AFRL/DELO), Kirtland AFB who are investigating high brightness semiconductor laser and double clad fiber sources. An additional focus of interest to this group is on feedback-induced instabilities in multimode semiconductor lasers, synchronization of chaotic semiconductor lasers and message encoding in chaotic signals. The upgraded computational capability has also fostered strong interactions with industry. We have worked directly with Textron Systems on a project of direct interest to the Air Force and have been working with Nortel Networks on calculating gain spectra for telecom's wavelength structures. Our collaboration with Opto Power of Tucson is still ongoing.

The recent discovery that a very small percentage of Nitrogen dopant (1% - 2%) can reduce the bandgap of GaAs or InGaAs by a few hundred meV thereby shifting the emission wavelength into the telecoms domain, has stimulated a spurt of activity in investigation of this new material. This material is very attractive for VCSEL structures, for example, because the technology already exists to grow GaAs multi-stack Bragg mirrors whereas InP is not a suitable material. We have computed optical gain spectra for this new material and demonstrated quantitative agreement with experimental measurements. The materials were grown and gain spectra measured as part of a collaboration between the University of Marburg and Infineon of Munich. The gain spectra calculations are compute intensive and were enabled by our enhanced supercomputing capability.

We have also carried out gain calculations for Textron Systems and Perkin Elmer as part of a project involving the development of high power pulsed laser sources for laser rangefinding applications. A collaboration has been established with Nortel Networks where we are computing gain spectra for 1.3u InGaAsP and InGaAlAs telecoms materials. These industry interactions are part of a larger scale interaction requiring gain calculations and device simulations.

An Interactive Supercomputing-based Simulator for High Power Laser Design The new computing hardware has enabled us to develop scalable interactive simulators for semiconductor lasers and amplifiers. We have now implemented current and refractive index profiling in order to suppress these unsaturated carrier regions and increase the overall brightness of the device. An overall goal of this project is to interface a fully 3D electrical and temperature transport model to the optical, carrier and temperature transport within the 2D active region of the device. This will enable us to quantify feedback from the active layer variables to the externally imposed electrical and thermal fields which strongly influence device performance. For example, accounting for the n- and p-carrier flow from some generally shaped contact down to the active region is critical if one is to quantify the role of current profiling through contact modification or proton bombardment. Likewise understanding the role of thermal flow is critical to efficient heat sink design for output power and brightness optimization studies. Another effort supported by the new hardware is the coupling of classical and quantum transport of carriers throughout realistic devices. Understanding carrier capture and escape in MQW devices is crucial when designing high modulation speed devices.

High Power Femtosecond Atmospheric Light Strings. The hardware is also proving invaluable in supporting the newly funded "High Power Femtosecond Laser Light Strings," (AFOSR F49620-00-1-0312). This phenomenon promises important applications in lightning control, LIDAR, remote sensing and energy delivery. This problem is extremely challenging computationally as the physical phenomenon is highly explosive, involving simultaneous compression in space and time. The new system has greatly enhanced our simulation capability allowing us to go to a full 3D+time simulation. This problem is extremely complex computationally due to the explosive chaotic light intensity spikes and accompanying plasma generation with sharp gradients due to the optical breakdown of air. We had to develop a parallel, adaptive mesh algorithm to resolve these fine scale details simultaneously in space and time. As we explore simulation of higher power pulses, available memory and processing requirements impose a major constraint. Extension of the simulation to vectorial (general initially polarized pulses) further increases the problem dimension.

Novel Ultrashort Pulse Phenomena. The augmented computing facility has allowed us to access the fully 2D and 3D vector Maxwell ultrashort pulse regime. In addition, we have been able to explore novel nonlinear effects due to ultrashort light pulse interactions with materials. At the vector Maxwell level, one is forced to resolve the underlying optical carrier wave and this places a significant restriction on the type of problem that can be solved. Significant progress has been made on a series of 1D and 2D problems. We are planning to use the new facility to study the interaction of intense femtosecond-duration linear and nonlinear light pulses with random scattering media in order to evaluate the feasibility of nonlinear pulses penetrating through atmospheric obscurants.

Double Clad Fiber Amplifiers and Lasers for High Brightness Applications. We are continuing the development of a fiber amplifier/laser model in response to the needs of the group at AFRL (DELO). The huge gain bandwidth of the doped fiber amplifiers and lasers, encompass thousands of