RECENT PUBLICATIONS BY LINCOLN LABORATORY STAFF MEMBERS

Beam combining of ytterbium fiber amplifiers

Augst, Steven J., Ranka, Jinendra K., Fan, T.Y., and Sanchez, Antonio, J. Opt. Soc. Am. B, Vol. 24, No. 8, August 2007, pp. 1707–1715.

Fiber lasers are well suited to scaling to high average power using beam-combining techniques. For coherent combining, optical phase-noise characterization of a ytterbium fiber amplifier is required to perform a critical evaluation of various approaches to coherent combining. For wavelength beam combining, we demonstrate good beam quality from the combination of three fiber amplifiers, and we discuss system scaling and design trades between laser linewidth, beam width, grating dispersion, and beam quality.

Silicon photonics for compact, energy-efficient interconnects

Barwicz, T., Byun, H., Gan, F., Holzwarth, C.W., Popović, M.A., Rakich, P.T., Watts, M.R., Ippen, E.P., Kärtner, F.X., Smith, H.I., Orcutt, J.S., Ram, R.J., Stojanovic, V., Olubuyide, O.O., Hoyt, J.L., Spector, S., Geis, M., Grein, M., Lyszczarz, T., and Yoon, J.U., J. Opt. Netw., Vol. 6, No. 1, January 2007, pp. 63–73.

The goal of the research program that we describe is to break the emerging performance wall in microprocessor development arising from limited bandwidth and density of on-chip interconnects and chip-to-chip (processor-to-memory) electrical interfaces.

Complementary metal-oxide semiconductor compatible photonic devices provide an infrastructure for deployment of a range of integrated photonic networks, which will replace state-of-the-art electrical interconnects, providing significant gains at the system level. Scaling of wavelength-division-multiplexing (WDM) architectures using high-index-contrast (HIC) waveguides offers one path to realizing the energy efficiency and density requirements of high data rate links. HIC microring-resonator filters are well suited to support add-drop nodes in dense WDM photonic networks with high aggregate data rates because they support high *Q*'s and, due to their traveling-wave character, naturally support physically separated input and drop ports.

A novel reconfigurable, "hitless" switch is presented that does not perturb the express channels either before, during, or after reconfiguration. In addition, multigigahertz operation of low-power, Mach–Zehnder silicon modulators as well as germanium-on-silicon photodiodes are presented.

pMATLAB parallel MATLAB library

Bliss, Nadya T., and Kepner, Jeremy, Int. J. High Perform. Comp. Appl., Vol. 21, No. 3, Fall 2007, pp. 336–359.

MATLAB has emerged as one of the languages most commonly used by scientists and engineers for technical computing, with approximately one million users worldwide. The compute intensive nature of technical computing means that many MATLAB users have codes that can significantly benefit from the increased performance offered by parallel computing. pMatlab provides this capability by implementing parallel global array semantics using standard operator overloading techniques. This paper describes the overall design and architecture of the pMatlab implementation. Performance is validated by implementing the HPC Challenge benchmark suite and comparing pMatlab performance with the equivalent C+MPI codes. These results indicate that pMatlab can often achieve comparable performance to C+MPI, usually at one tenth the code size.

Speaker verification using support vector machines and high-level features

Campbell, William M., Campbell, Joseph P., Gleason, Terry P., Reynolds, Douglas A., and Shen, Wade, IEEE Trans. on Audio, Speech, and Language Process., Vol. 15, No. 7, September 2007, pp. 2085–2094.

High-level characteristics such as word usage, pronunciation, phonotactics, and prosody have seen a

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resurgence for automatic speaker recognition over the last several years. With the availability of many conversation sides per speaker in current corpora, high-level systems now have the amount of data needed to sufficiently characterize a speaker. Although a significant amount of work has been done in finding novel high-level features, less work has been done on modeling these features.

We describe a method of speaker modeling based upon support vector machines. Current high-level feature extraction produces sequences or lattices of tokens for a given conversation side. These sequences can be converted to counts and then frequencies of n-gram for a given conversation side. We use support vector machine modeling of these n-gram frequencies for speaker verification. We derive a new kernel based upon linearizing a log-likelihood ratio scoring system. Generalizations of this method are shown to produce excellent results on a variety of high-level features. We demonstrate that our methods produce results significantly better than standard log-likelihood ratio modeling. We also demonstrate that our system can perform well in conjunction with standard cepstral speaker recognition systems.

Machine learning for computer security

Chan, Philip K., and Lippmann, Richard P., J. Machine Learning, Vol. 7, December 2006, pp. 2669–2672.

The prevalent use of computers and the Internet has enhanced the quality of life for many people, but it has also attracted undesired attempts to undermine these systems. This special topic contains several research studies on how machine learning algorithms can help improve the security of computer systems.

Terahertz interferometer that senses vibrations behind barriers

Chen, Jerry C., and Kaushik, Sumanth, IEEE Photonics Technol. Lett., Vol. 19, No. 7, April 1, 2007, pp. 486–488.

A terahertz sensor that measures vibrations behind optically opaque barriers (cardboard, plastic, wool, cotton) is described and demonstrated. Using interferometric techniques, submicrometer displacements can be resolved. Measured spectral response agrees with commercial vibrometer.

Bulk GaN crystal growth by the high-pressure ammonothermal method

D'Evelyn, M.P., Hong, H.C., Park, D.-S., Lu, H., Kaminsky, E., Melkote, R.R., Perlin, P., Mesczynski, M., Porowski, S., and Molnar, R.J., J. Cryst. Growth, Vol. 300, No. 1, March 1, 2007, pp. 11–16.

The rapidly growing gallium nitride device industry continues to be in dire need of high quality, cost effective native substrates. Considerable progress has been made with pseudo-bulk substrates synthesized by hydride vapor phase epitaxy, but true bulk methods promise both superior quality and reduced cost.

We give an overview of the high-pressure ammonothermal method developed by General Electric, based on adaptation of high-pressure apparatus developed for diamond growth, together with appropriate raw materials and methods. We describe recent progress, including characterization of and reductions in impurity concentrations, wafering, and successful fabrication of homoepitaxial laser diodes on GE substrates.

Cryogenic YB^{3+}-doped solid-state lasers

Fan, Tso Yee, Ripin, Daniel J., Aggarwal, Roshan L., Ochoa, Juan R., Chann, Bien, Tilleman, Michael, and Spitzberg, Joshua D., IEEE J. Sel. Topics in Quantum Electron., Vol. 13, No. 3, May/June 2007, pp. 448–459.

Cryogenically cooled solid-state lasers promise a revolution in power scalability while maintaining a good beam quality because of significant improvements in efficiency and thermo-optic properties. This is particularly true for Yb^{3+} lasers because of their relatively low quantum defect and relatively broadband absorption even at cryogenic temperatures.

Thermo-optic properties of host materials, including thermal conductivity, thermal expansion, and refractive index at low temperature, are reviewed and data presented for YAG (ceramic and single crystal), GGG, $GdVO_4$, and Y_2O_3. Spectroscopic properties of Yb:YAG and Yb:$LiYF_4$ (YLF) including absorption cross sections, emission cross sections, and fluorescence lifetimes at cryogenic temperatures are characterized. Recent experiments have pushed the power from an end-pumped cryogenically cooled Yb:YAG laser to 455-W continuous-wave output power from 640-W incident pump power at an M^2 of 1.4.

Optimum quantum error recovery using semidefinite programming

Fletcher, Andrew S., Shor, Peter W., and Win, Moe Z., Phys. Rev. A, Vol. 75, No. 1, 2007.

Quantum error correction (QEC) is an essential element of physical quantum information processing systems. Most QEC efforts focus on extending classical error correction schemes to the quantum regime. The input to a noisy system is embedded in a coded subspace, and error recovery is performed via an operation designed to perfectly correct for a set of errors, presumably a large subset of the physical noise process.

We examine the choice of recovery operation. Rather than seeking perfect correction on a subset of errors, we seek a recovery operation to maximize the entanglement fidelity for a given input state and noise model. In this way, the recovery operation is optimal for the given encoding and noise process. This optimization is shown to be calculable via a semidefinite program, a well-established form of convex optimization with efficient algorithms for its solution. The error recovery operation may also be interpreted as a combining operation following a quantum spreading channel, thus providing a quantum analogy to the classical diversity combining operation.

Extending 193nm immersion with hybrid optical maskless lithography

Fritze, Michael, Bloomstein, Theodore M., Tyrrell, Brian M., and Rothschild, Mordechai, Solid State Technol., Vol. 49, No. 9, September 2006, pp. 41–43.

Immersion-based optical lithography techniques at 193 nm have made great progress and are viewed by many as an option for the 45 nm node. But options for the 32 nm node are uncertain. EUV is one possibility. However, critical technological issues regarding light sources, masks, resists, and other must first be solved. The only other viable option appears to be enhancing 193 nm immersion by multiple exposures. The key question for this option is what type of multiple exposure solution is most economical and practical to implement. This article discusses a specific type of multiple exposure optical approach we refer to as hybrid optical maskless lithography.

Self-stabilization of an actively mode-locked semiconductor-based fiber-ring laser for ultralow jitter

Gee, S., Ozhara, S., Quinlan, F., Plant, Jason J., Juodawlkis, P.W., and Delfyett, P.J., IEEE Photonics Technol. Lett., Vol. 19, No. 7, April 1, 2007, pp. 498–500.

Noise characteristics are studied for a self-stabilized laser utilizing the interplay between the intracavity dispersion and the optical frequency shift. The noise suppression bandwidth of this scheme is from 0 to ~100 KHz and showed the reduction of residual timing jitter (integrated from 0.9 Hz to 1MHz) from 2.2 fs to 660 attosecond, which represents, to our knowledge, the lowest timing jitter reported for an actively mode-locked laser.

CMOS-compatible all-Si high-speed waveguide photodiode with high responsitivity in near-infrared communication band

Geis, Michael W., Spector, Steven Jay, Grein, Matthew E., Schulein, Robert T., Yoon, Jung Uk, Lennon, Donna M., Deneault, Sandra J., Gan, Fuwan, Kaertner, Franz X., and Lyszczarz, Theodore M., IEEE Photonics Technol. Lett., Vol. 19, No. 3, February 1, 2007, pp. 152–154.

Submicrometer silicon photodiode waveguides, fabricated on silicon-on-insulator substrates, have photoresponse from <1270 to 1740 nm (0.8 AW^{-1} at 1550 nm) and a 3-dB bandwidth of 10 to 20 GHz. The p-i-n photodiode waveguide consists of an intrinsic waveguide 500 × 250 nm where the optical mode is confined and two thin, 50-nm-thick, doped Si wings that extend 5 μm out from either side of the waveguide. The Si wings, which are doped one p-type and the other n-type, make electric contact to the waveguide with minimal effect on the optical mode. The edges of the wings are metalized to increase electrical conductivity. Ion implantation of Si^{+} 1×10^{13} cm^{-1} at 190 keV into the waveguide increases the optical absorption from 2–3 dB cm^{-2} to 200–100 dB cm^{-1} and causes the generation of a photocurrent when the waveguide is illuminated with subbandgap radiation. The diodes are not damaged by annealing to 450°C for 15 s or 300°C for 15 min. The photoresponse and thermal stability is believed due to an oxygen stabilized divacancy complex formed during ion implantation.

Recent Publications

Measurement of aerosol-particle trajectories using a structured laser beam

Herzog, William D., Tysk, Shane M., Tardiff, David W., Cappiello, Gregory G., Jong, Jason M., Jeys, Thomas H., Hoffeld, Ronald H., Sanchez-Rubio, Antonio, and Daneu, Vincenzo, Appl. Opt., Vol. 46, No. 16, June 1, 2007, pp. 3150–3155.

What is believed to be a new concept for the measurement of micrometer-sized particle trajectories in an inlet air stream is introduced. The technique uses a light source and a mask to generate a spatial pattern of light within a volume in space. Particles traverse the illumination volume and elastically scatter light to a photodetector where the signal is recorded in time. The detected scattering waveform is decoded to find the particle trajectory. A design is presented for the structured laser beam, and the accuracy of the technique in determining particle position is demonstrated. It is also demonstrated that the structured laser beam can be used to measure and then correct for the spatially dependent instrument-response function of an optical-scattering-based particle-sizing system for aerosols.

Reconfigurable delay time polymer planar lightwave circuit for an X-band phased-array antenna demonstration

Howley, Brie, Wang, Xiaolong, Chen, Maggie, and Chen, Ray T., J. Lightwave Technol., Vol. 25, No. 3, March 2007, pp. 883–890.

A 4-bit polymer optoelectronic true-time delay (TTD) device is demonstrated. The planar lightwave circuit (PLC) is composed of monolithically integrated low-loss passive polymer waveguide delay lines and five cascaded 2 × 2 polymer thermooptic switches. Waveguide junction offsets and air trenches simultaneously reduce the bending loss and device area. Simulations are used to optimize the trench and offset structures for fabrication. The 16 time delays generated by the device are measured to be in the range from 0 to 177 ps in 11.8-ps increments. The packaged PLC has an insertion loss of up to 14.9 dB, and the delay switching speed is 2 ms. An eight-element X-band phased-array antenna system is constructed to demonstrate the beam-steering capabilities of the 4-bit-delay devices. The TTD devices are shown to steer the far-field radiation pattern between 0 and –14.5°.

Heterojunction thermophotovoltaic devices with high voltage factor

Huang, Robin K., Ram, Rajeev J., Manfra, Michael J., Connors, Michael K., Missaggia, Leo J., and Turner, George W., J. Appl. Phys., Vol. 101, No. 4, February 15, 2007.

We have demonstrated a heterojunction thermophotovolatic device. The 0.54 eV band gap device has an open-circuit voltage of 360 mV for a short circuit current density of 2.7 A/cm^2 at T = 25°C, which is higher than the open-circuit voltage realized in any other thermophotovoltaic device previously demonstrated having comparable band gaps.

High-brightness wavelength beam combined semiconductor laser diode arrays

Huang, Robin K., Chann, Bien, Missaggia, Leo J., Donnelly, Joseph P., Harris, Christopher T., Turner, George W., Goyal, Anish K., Fan, Tso Yee, and Sanchez-Rubio, Antonio, IEEE Photonics Technol. Lett., Vol. 19, No. 4, February 15, 2007, pp. 209–211.

We report the wavelength beam combining of an array of high-power high-brightness 970-nm slab-coupled optical waveguide lasers. A 50-W peak power under quasi-continuous-wave (CW) operation was measured in an output beam with a beam quality of $M_{x,y}^2 = 1.2$, and 30 W under CW operation was measured with a beam quality of $M_{x,y}^2 = 2$.

Constriction-limited detection efficiency of superconducting nanowire single-photon detectors

Kerman, Andrew J., Dauler, Eric A., Yang, Joel K.W., Rosfjord, Kristine M., Anant, Vikas, Berggren, Karl K., Gol'tsman, Gregory N., and Voronov, Boris N., Appl. Phys. Lett., Vol. 90, No. 10, March 5, 2007, pp. 101110-1–101110-3.

We investigate the source of the large variations in the observed detection efficiencies of superconducting nanowire single-photon detectors between many nominally identical devices. Through both electrical and optical measurements, we infer that these variations arise from "constrictions": highly localized regions of the nanowires where the effective cross-sectional area for superconducting current is reduced. These constrictions limit the bias-current density to well below its critical value over the remainder of the wire, and thus prevent the detection efficiency from reaching the high values that occur in these devices when they are biased near the critical current density.

Boundary controllability of Maxwell's equations with nonzero conductivity inside a cube, I: Spectral controllability

Krigman, Steven S., and Wayne, C.E., Math. Anal. Appl., Vol. 329, No. 2, May 15, 2007, pp. 1375–1396.

This is the first paper in a series of two. In both papers, we consider the question of control of Maxwell's equations in a homogeneous medium with positive conductivity by means of boundary surface currents. The domain under consideration is a cube, where the conductivity is allowed to take on any nonnegative values. An additional restriction imposed in order to make this problem more suitable for practical implementations is that the controls are applied over only one face of the cube.

In this paper, the method of moments is employed to establish spectral controllability for the above case (meaning that any finite combination of eigenfunctions is controllable). In the companion paper (J. Math. Anal. Appl., 2006, doi:10.1016/j.jmaa2006.02.102), it is established, by modifying the calculations in H.O. Fattorini ("Estimates for sequences biorthogonal to certain complex exponentials and boundary control of the wave equation," Lecture Notes in Control and Inform. Sci., vol. 2, Springer, Berlin, 1977, pp. 111–124), that exact controllability fails for this geometry regardless of the size of the conductivity term. However, we will also establish in part 2 that controllability of solutions that are smooth enough that the Fourier coefficients of their initial data decay at a suitable exponential rate.

Boundary controllability of Maxwell's equations with nonzero conductivity inside a cube, II: Lack of exact controllability and controllability for very smooth solutions

Krigman, Steven S., and Wayne, C.E., J. Math. Anal. Appl., Vol. 329, No. 2, May 15, 2007, pp. 1355–1374.

This is the second paper in a two part series. In part 1 (J. Math. Anal. Appl., 2006, doi:10.1016/j.jmaa2006.06.101) we show that a system of Maxwell's equations for a homogeneous medium in a cube with nonnegative conductivity possesses the property that any finite combination of eigenfunctions is controllable (spectral controllability) by means of boundary surface currents applied over only one face of the cube.

In the present paper it is established by modifying the calculations in H.O. Fattorini ("Estimates for sequences biorthogonal to certain complex exponentials and boundary control of the wave equation," Lecture Notes in Control and Inform. Sci., vol. 2, Springer, Berlin, 1977, pp. 111–124) spectral controllability is the strongest result possible for this geometry, since the exact controllability fails regardless of the size of the conductivity term. However, we do establish that controllability of solutions are smooth enough that the Fourier coefficients of their initial data decay at an appropriate exponential rate. This does not contradict the lack of exact controllability since in any Sobolev space there are initial conditions which violate these restrictions.

Nonlinear resonant behavior of a dispersive readout circuit for a superconducting flux qubit

Lee, Janice C., Oliver, William D., Berggren, Karl K., and Orlando, T.P., Phys. Rev. B, Condens. Matter, Vol. 75, No. 14, April 2007, pp. 144505-1–144505-10.

A nonlinear resonant circuit comprising a SQUID magnetometer and a shunting capacitor is studied as a readout scheme for a persistent-current qubit. The flux state of the qubit is detected as a change in the Josephson inductance of the SQUID magnetometer, which in turn mediates a shift in the resonant frequency of the readout circuit. The nonlinearity and resulting hysteresis in the resonant behavior are characterized as a function of the power of both the input drive and the associated resonance-peak response. Numerical simulations based on a nonlinear circuit model show that the observed nonlinearity is dominated by the effect due to an AC flux rather than current bias through the Josephson inductor.

Real-time implementation of a frequency shaping controller on a cantilever beam

Lewis, Brian M., and Tran, H.T., Appl. Num. Math., Vol. 57, No. 5–7, May–July 2007, pp. 778–790 (ICSC05, Int. Conf. on Scientific Computing, 4–8 June 2005).

In this paper, we present the real time implementation of a control methodology for the attenuation of beam vibrations in a smart structure paradigm caused by a narrow-band exogenous force. By narrow-band exogenous force we mean a periodic force over a narrow frequency band or a particular

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harmonic. The particular control method is based on the minimization of a frequency dependent quadratic cost functional. This control method has been used successfully in various applications; however, this investigation differs from other works in that it emphasizes the real-time implementation of this model-based control methodology using real-time partial state measurements.

Impact of photoacid generator leaching on optics photocontamination in 193-nm immersion lithography

Liberman, Vladimir, Rothschild, Mordechai, Palmacci, Stephen T., and Grenville, Andrew, J. Micro/Nanolith, MEMS MOEMS, Vol. 6, No. 1, January-March 2007, pp. 013001-1–013001-7.

Leaching of resist components into water has been reported in several studies. Even low dissolution levels of photoacid generator (PAG) may lead to photocontamination of the last optical surface of the projection lens. To determine the impact of this phenomenon on optics lifetime, we initiate a set of controlled studies, where predetermined amounts of PAG are introduced into pure water and the results monitored quantitatively. The study identifies the complex, nonlinear paths leading to photocontamination of the optics. We also discover that spatial contamination patterns of the optics are strongly dependent on the flow geometry. Both bare SiO_2 surfaces as well as coated CaF_2 optics are studied. We find that for all surfaces, at concentrations typical of leached PAG, below 500 ppb, the in situ self-cleaning processes prevent contamination of the optics.

Initial conditions, generalized functions, and the Laplace transform

Lundberg, Kent H., Miller, Haynes R., and Trumper, David L., IEEE Control Syst. Mag., Vol. 27, No. 1, February 2007, pp. 22–35.

The unilateral Laplace transform is widely used to analyze signals, linear models, and control systems, and is consequently taught to most engineering undergraduates. In our courses at MIT in electrical engineering and computer science, mathematics, and mechanical engineering, we have found some significant pitfalls associated with teaching students to understand and apply the Laplace transform.

We have independently concluded that one reason students find the Laplace transform difficult is that there is significant confusion present in many of the standard textbook presentations of this subject. These troubles arise from a reluctance to use the generalized derivative. One of the goals of this article is to show that a formal but easily understood treatment can be based on generalized functions. In brief, the fact that the derivative at a discontinuity produces a delta function must be embraced from the outset.

We highlight Laplace transform definitions and properties that allow a readily taught and correct analysis of dynamic systems incorporating nonzero initial conditions and where the system is driven by signals that include singularity functions at the origin.

Robust speaker recognition in noisy conditions

Ming, Ji, Hazen, Timothy J., Glass, James R., and Reynolds, Douglas A., IEEE Trans. Speech Audio Process., Vol. 15, No. 5, July 2007, pp. 1711–1723.

This paper investigates the problem of speaker identification and verification in noisy conditions, assuming that speech signals are corrupted by environmental noise, but knowledge about the noise characteristics is not available. This research is motivated in part by the potential application of speaker recognition technologies on handheld devices or the Internet. While the technologies promise an additional biometric layer of security to protect the user, the practical implementation of such systems faces many challenges. One of these is environmental noise. Due to the mobile nature of such systems, the noise sources can be highly time-varying and potentially unknown. This raises the requirement for noise robustness in the absence of information about the noise. This paper describes a method that combines multicondition model training and missing-feature theory to model noise with unknown temporal-spectral characteristics.

Passive source localization using an airborne sensor array in the presence of manifold perturbations

Mir, Hasan S., Sahr, John D., Hatke, Gary F., and Keller, Catherine M., IEEE Trans. Signal Proc., Vol. 55, No. 6, June 2007, pp. 2486–2496.

This paper studies localizing sources of electromagnetic energy using a passive sensor array whose manifold is only nominally known.

The problem of source localization is studied in the context of an airborne array that is able to observe a ground-based source from multiple angles. External and self-calibration algorithms are developed as a means to obtain accurate source localization estimates when the sensor manifold is perturbed. External calibration establishes the expected difference between the actual and modeled array manifold using signals at known locations. Self-calibration assumes that this expected difference is known only approximately and relies on signals of opportunity in the environment to provide updates. Several novel calibration algorithms are proposed, and their performance is tested on experimental data. The results indicate that significant performance gains are achieved with the use of the proposed calibration algorithms.

SAR image autofocus by sharpness optimization: a theoretical study

Morrison, Robert L., Jr., Do, Minh N., and Munson, David C., IEEE Trans. Image Process., Vol. 16, No. 9, September 2007, pp. 2309–2321.

Synthetic aperture radar (SAR) autofocus techniques that optimize sharpness metrics can produce excellent restorations in comparison with conventional autofocus approaches. To help formalize the understanding of metric-based SAR autofocus methods, and to gain more insight into their performance, we present a theoretical analysis of these techniques using simple image models.

Specifically, we consider the intensity-squared metric, and a dominant point-targets image model, and derive expressions for the resulting objective function. We examine the conditions under which the perfectly focused image models correspond to stationary points of the objective function. A key contribution is that we demonstrate formally, for the specific case of intensity-squared minimization autofocus, the mechanism by which metric-based methods utilize the multichannel defocusing model of SAR autofocus to enforce the stationary point property for multiple image columns.

Furthermore, our analysis shows that the objective function has a special separable property through which it can be well approximated locally by a sum of 1-D functions of each phase error component. This allows fast performance through solving a sequence of 1-D optimization problems for each phase component simultaneously. Simulation results using the proposed models and actual SAR imagery confirm that the analysis extends well to realistic situations.

Overview of nonlinearity in HTS: what we have learned and prospects for improvement

Oates, Daniel E., J. Supercond. Novel Magnetism, Vol. 20, No. 1, January 2007, pp. 3–12.

The linear surface resistance of the HTS materials is low enough to support a variety of applications that can surpass conventional technology. However, nonlinearity in the form of intermodulation distortion (IMD) is a serious limiting effect for some applications. The nonlinear effects are only weakly correlated with the low-power surface impedance, and considerable material variation has been the hallmark of IMD. With improvement in film quality, the intrinsic nonlinearity now seems to be the most important source of IMD. Presented here is a brief review of the experimental situation and a comparison with the theories of intrinsic nonlinearity.

Membrane introduction/laser photoionization time-of-flight mass spectrometry

Oser, Harald, Coggiola, Michael J., Young, Steven E., Crosley, David R., Hafer, Virginia K., and Grist, Gregory, Chemosphere, Vol. 67, No. 9, April 2007, pp. 1701–1708.

Two-photon resonance enhanced multiphoton ionization (REMPI) has been shown to be a unique ionization method for mass spectrometry, exhibiting both high sensitivity and chemical selectivity. Because REMPI is a gas-phase method, its applications have been limited either to direct analysis of vapor phase samples, or in conjunction with an initial laser desorption or other vaporization step.

We describe here for the first time a combination of membrane introduction mass spectrometry (MIMS) and REMPI with time-of-flight mass spectrometry, which allows for the direct analysis of trace amounts of organic compounds in water samples. Our objective was to detect very low levels of aromatic contaminants, particularly benzene, toluene, and xylene, in aqueous solutions without interference due to the water. We have measured limits of detec-

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tion for selected aromatics in water below 1 part-per-trillion with an averaging time of less than 10 s using a continuous sample flow.

Network layer performance of a satellite network with dynamic link-layer resource allocation

Pandya, Julee, Narula-Tam, Aradhana, Yao, Huan, and Wysocarski, Jeffrey S., Int. J. Satell. Commum. Network., Vol. 25, No. 2, Mar-Apr 2007, pp. 217–235.

Future packet switched military satellite communication networks are being designed with dynamic resource allocation on the up- and down-links in order to efficiently utilize the limited radio frequency resources. The resource allocation algorithms must be designed to achieve good system efficiency and user performance in addition to optimizing link-layer efficiency. An OPNET simulation environment is used to model and evaluate system performance for a satellite network with dynamically provisioned up and down-links under dynamic traffic and channel variations. Link-layer resource allocation algorithms are developed and performance is evaluated in terms of application layer throughput, loss, delay, and jitter as well as system resource utilization.

Low-noise optical injection locking of a resonant tunneling diode to a stable optical frequency comb

Ramond, T.M., Hollberg, L., Juodawlkis, P.W., and Calawa, S.D., Appl. Phys. Lett., Vol. 90, No. 17, April 23, 2007, pp. 171124-1–171124-3.

Optical injection locking of a resonant tunneling diode (RTD) oscillator has been demonstrated using ultrashort pulses from a mode-locked Ti:sapphire laser operating at a 1 GHz pulse rate. The source of the optical signal is a mode-locked femtosecond laser whose optical frequency comb is phase locked to a H-maser stabilized frequency synthesizer. An exceptionally large capture range of more than 5 MHz is observed. The system produces stable microwave signals with low phase noise, which at 1 GHz is less than –74 dBc/Hz for a 10 Hz offset. The noise of the microwave injection-locked RTD signal matches that of the input optical pulses.

Loss-induced limits to phase measurement precision with maximally entangled states

Rubin, Mark A., and Kaushik, Sumanth, Phys. Rev. A, At. Mol. Opt. Phys., Vol. 75, No. 5, May 2007, pp. 053805-1–053805-6.

The presence of loss limits the precision of an approach to phase measurement using maximally entangled states, also referred to as NOON states. A calculation using a simple beam-splitter model of loss shows that, for all nonzero values L of the loss, phase measurement precision degrades with increasing number N of entangled photons for N sufficiently large. For L above a critical value of approximately 0.785, phase measurement precision degrades with increasing N for all values of N. For L near zero, phase measurement precision improves with increasing N down to a limiting precision of approximately $1.018L$ radians, attained at N approximately equal to $2.218/L$, and degrades as N increases beyond this value. Phase measurement precision with multiple measurements and a fixed total number of photons N_T is also examined.

Optimized growth of lattice-matched $In_xAl_{1-x}N$/GaN heterostructures by molecular beam epitaxy

Schmult, S., Siegrist, T., Sergent, A.M., Manfra, M.J., and Molnar, R.J., Appl. Phys. Lett., Vol. 90, No. 2, January 8, 2007, pp. 021922-1–021922-3.

The authors present a systematic study on the growth of the ternary compound $In_xAl_{1-x}N$ by molecular beam epitaxy. This work concentrates on In mole fractions x around 0.17, as this composition is in-plane lattice matched to GaN. At a growth temperature of 540°C, high quality material was obtained using a total metal to nitrogen flux ratio of ~1. Using these growth parameters, high quality GaN/InAlN superlattices were obtained without growth interruptions.

Contaminant detection, identification, and quantification using a microchip laser fluorescence sensor

Sinfield, Joseph V., Hemond, Harold F., Germaine, John T., and Johnson, Bernadette, J. Environmental Engineering, Vol. 133, No. 3, March 2007, pp. 346–351.

This paper describes a series of laboratory tests conducted to assess the performance of a novel fluorescence-based in situ sensor for environmental contaminants. The sensor, which can be deployed downhole in a monitoring well, or incorporated into the shaft of a cone penetrometer, is less than 4 cm in diameter and uses a miniature microchip laser that produces ~200 ps ultraviolet pulses at a high repetition rate (~10 kHz) to

excite fluorescence in a wide range of compounds. Results from laser induced fluorescence tests on single compound aqueous solutions of benzene, toluene, and o-xylene demonstrate the sensor's ability to perform contaminant analyses on compounds with fluorescence lifetimes on the order of 1 ns. A linear relationship between contaminant concentration and fluorescence intensity was observed for concentrations over several orders of magnitude from the sensor's detection limit (<1 ppm for o-xylene) to solutions of pure BTX compounds at aqueous solubility. Owing to the microchip laser's short pulse length, fluorescence lifetimes were obtained directly from measurements without the need for spectral deconvolution. Analysis of data from these tests highlights the importance of differentiating a sensor's ability to detect, identify, and quantify compounds of interest—performance thresholds that define the device's potential applications.

Optical phased array power penalty analysis

Tsui, Jing M., Thompson, Charles, and Roth, Jeffrey M., Opt. Express, Vol. 15, No. 8, April 16, 2007, pp. 5179–5190.

This paper investigates the power penalty from optical phased arrays used for wide-angle beam steering of optical communication signals. The analysis studies the effect of aperture size, data rate, modulation format, and diffraction angle on digital lightwave signals. The results show increasing power penalties for larger angles, aperture sizes, and data rates. At a 10° steering angle, 10-cm aperture, and for both on-off keying (OOK) and differential phase-shift keying (DPSK) the 2.5-Gb/s power penalty is approximately 1.0 dB, while at 10 Gb/s the penalty increases to 7.7 dB for OOK and 7.8 dB for DPSK.

Stable, tunable calibration source for large-beam optical systems

Ulmer, Todd G., Raudenbush, Amy C., and Loriaux, Vicky M., Appl. Opt., Vol. 46, No. 5, February 10, 2007, pp. 669–675.

An optical calibration source for free-space systems with large beams is presented. It produces a 2 W, 370 mm beam tunable from 1545–1570 nm with a wavefront error of $<\lambda 15$ peak to valley and $<0.013\lambda$ rms at 1550 nm, power stability of <±0.02 dB, arbitrarily selected polarization, and polarization stability of <± h in orientation and <±0.02/h in ellipticity.

Microwave-induced cooling of a superconducting qubit

Valenzuela, Sergio O., Oliver, William D., Berns, David M., Berggren, Karl K., Levitov, Leonid S., and Orlando, Terry P., Sci., Vol. 314, No. 5805, 8 December 2006, pp. 1589–1592.

We demonstrated microwave-induced cooling in a superconducting flux qubit. The thermal population in the first-excited state of the qubit is driven to a higher-excited state by way of a sideband transition. Subsequent relaxation into the ground state results in cooling. Effective temperatures as low as ≈3 millikelvin are achieved for bath temperatures of 30 to 400 millikelvin, a cooling factor between 10 and 100. This demonstration provides an analog to optical cooling of trapped ions and atoms and is generalizable to other solid-state quantum systems. Active cooling of qubits provides a means for qubit-tate preparation with improved fidelity and for suppressing decoherence in multi-qubit systems.

Surface reflectance estimation using prior spatial and spectral information

Viggh, Herbert E.M., and Staelin, David H., IEEE Trans. Geosci. Remote Sens., Vol. 45, No. 9, September 2007, pp. 2928–2939.

Surface Prior-Information Reflectance Estimation (SPIRE) algorithms estimate changes in spectral reflectance using imperfect prior spatial and spectral information. This paper combines spectral and spatial processing to estimate local changes in spectral reflectance between pairs of spectral images under spatially and spectrally varying multiplicative and additive noise, which arise from variations in illumination and atmospheric effects. Tests on Hyperspectral Digital Imagery Collection Experiment visible near-infrared–shortwave infrared data demonstrated the algorithm's superior ability to estimate absolute reflectance changes under varying illumination conditions. SPIRE performance was nearly identical to the empirical line method (ELM) ground-truth-based atmospheric compensation results and was better than the physics-based ATmospheric REMoval (ATREM) code overall, particularly, under high clouds and haze. A "Selective SPIRE" technique that chooses between combined-spatial/spectral and spectral-only SPIRE reflectance estimates was developed.