Photonic Communications Laboratory

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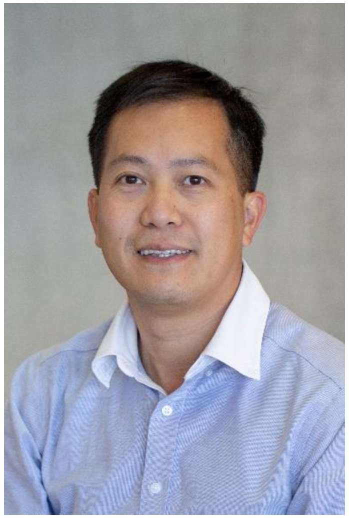
OPTI 587l - Instructor



Khanh Kieu

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Education:

- Ph.D., University of Arizona, 2007
- M.S., University of Arizona, 2006
- M.S., St. Petersburg State University of Information Technologies, Mechanics and Optics (Russia), 2004
- B.S., St. Petersburg State University of Information Technologies, Mechanics and Optics (Russia), 2002

Specific Research Interests:

Ultrafast fiber lasers
Nonlinear fiber optics
Nonlinear spectroscopy and frequency comb
Microresonators and applications
Biomedical imaging based on supercontinuum and ultrafast fiber light sources
All-optical switching
Micromachining with femtosecond lasers
Fiber optical sensors

Goals

1. Introduction to fiber optics. Hand-on experience
2. Measurement techniques and data presentation
3. Real research experience in fiber lasers (voluntary based)
4. Broader topics

Class Requirements

- Lecture and lab participation 10%
- Lab reports 80%
- Final presentation 10%

Reports should be quantitative and concise. An acceptable format for a report should include the following:

  - Experimental objectives – what is the purpose of the experiment and what do you hope to accomplish in the lab. 15%
  - Experimental Setup- Show/Explain the experimental arrangement. 15%
  - Experimental data and analysis – Report all experimental data recorded in a clear, easy to follow format. Indicate the error margin for your data and possible sources of error. 35%
  - Discussion and Summary – Were the objectives accomplished? Any new ideas to improve the measurement? 35%

TA

Yukun Qin (yukunqin@email.arizona.edu)

Availability for lab sessions: 2-5pm, Monday through Thursday

Class website

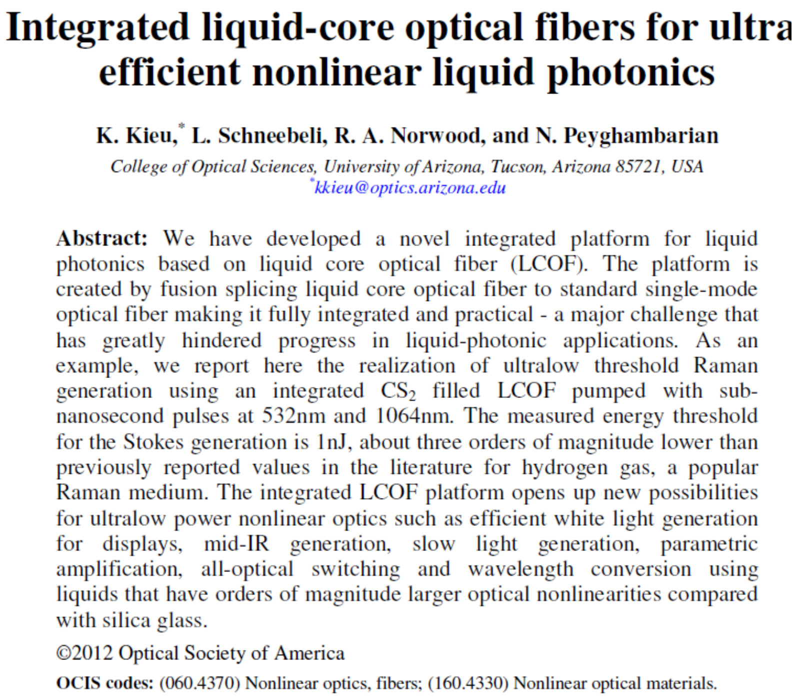
http://wp.optics.arizona.edu/kkieu/courses/opti-587l.htm

Projects

1. Handling optical fibers, numerical aperture
2. Measurement of fiber attenuation
3. Connectors and splices
4. Free space coupling of laser into fibers
5. Bending loss in optical fibers
6. Components for fiber communication and fiber lasers
7. Fiber lasers and amplifiers
8. Mode-locked fiber lasers
9. Soliton transmission in optical network
10. Fiber optics interferometric sensors

Advanced Projects

- Not required for the class- voluntary work



Integrated liquid-core optical fibers for ultra efficient nonlinear liquid photonics

K. Kieu,[*] **L. Schneebeli, R. A. Norwood, and N. Peyghambarian**

College of Optical Sciences, University of Arizona, Tucson, Arizona 85721, USA
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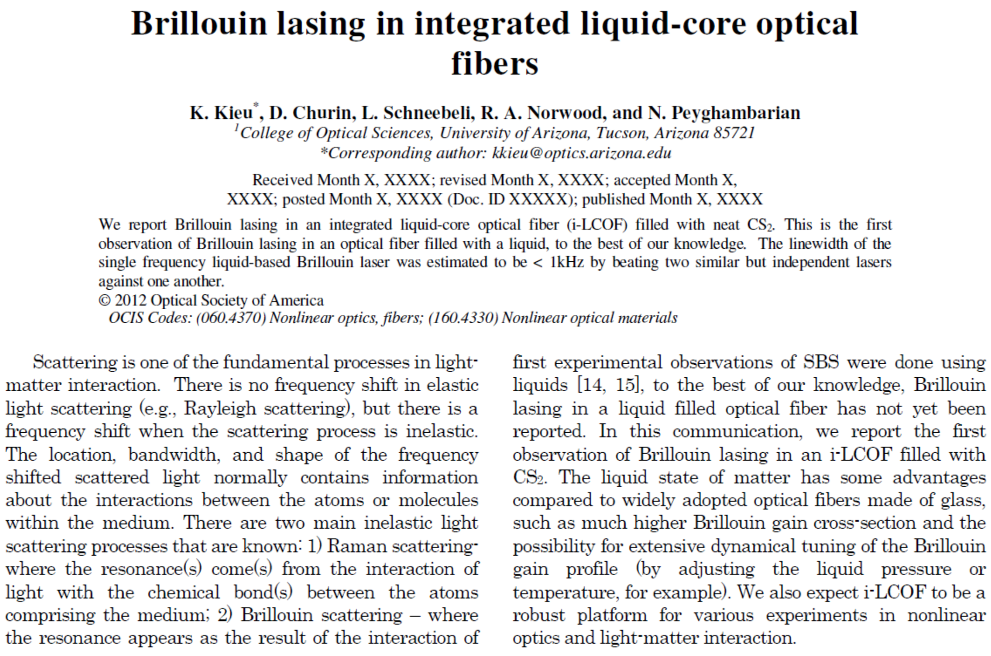
Abstract: We have developed a novel integrated platform for liquid photonics based on liquid core optical fiber (LCOF). The platform is created by fusion splicing liquid core optical fiber to standard single-mode optical fiber making it fully integrated and practical - a major challenge that has greatly hindered progress in liquid-photonic applications. As an example, we report here the realization of ultralow threshold Raman generation using an integrated CS_2 filled LCOF pumped with sub-nanosecond pulses at 532nm and 1064nm. The measured energy threshold for the Stokes generation is 1nJ, about three orders of magnitude lower than previously reported values in the literature for hydrogen gas, a popular Raman medium. The integrated LCOF platform opens up new possibilities for ultralow power nonlinear optics such as efficient white light generation for displays, mid-IR generation, slow light generation, parametric amplification, all-optical switching and wavelength conversion using liquids that have orders of magnitude larger optical nonlinearities compared with silica glass.

OCIS codes: (060.4370) Nonlinear optics, fibers; (160.4330) Nonlinear optical materials.

Spring 2011



Brillouin lasing in integrated liquid-core optical fibers

K. Kieu[*]**, D. Churin, L. Schneebeli, R. A. Norwood, and N. Peyghambarian**
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We report Brillouin lasing in an integrated liquid-core optical fiber (i-LCOF) filled with neat CS_2. This is the first observation of Brillouin lasing in an optical fiber filled with a liquid, to the best of our knowledge. The linewidth of the single frequency liquid-based Brillouin laser was estimated to be < 1kHz by beating two similar but independent lasers against one another.

OCIS Codes: (060.4370) Nonlinear optics, fibers; (160.4330) Nonlinear optical materials

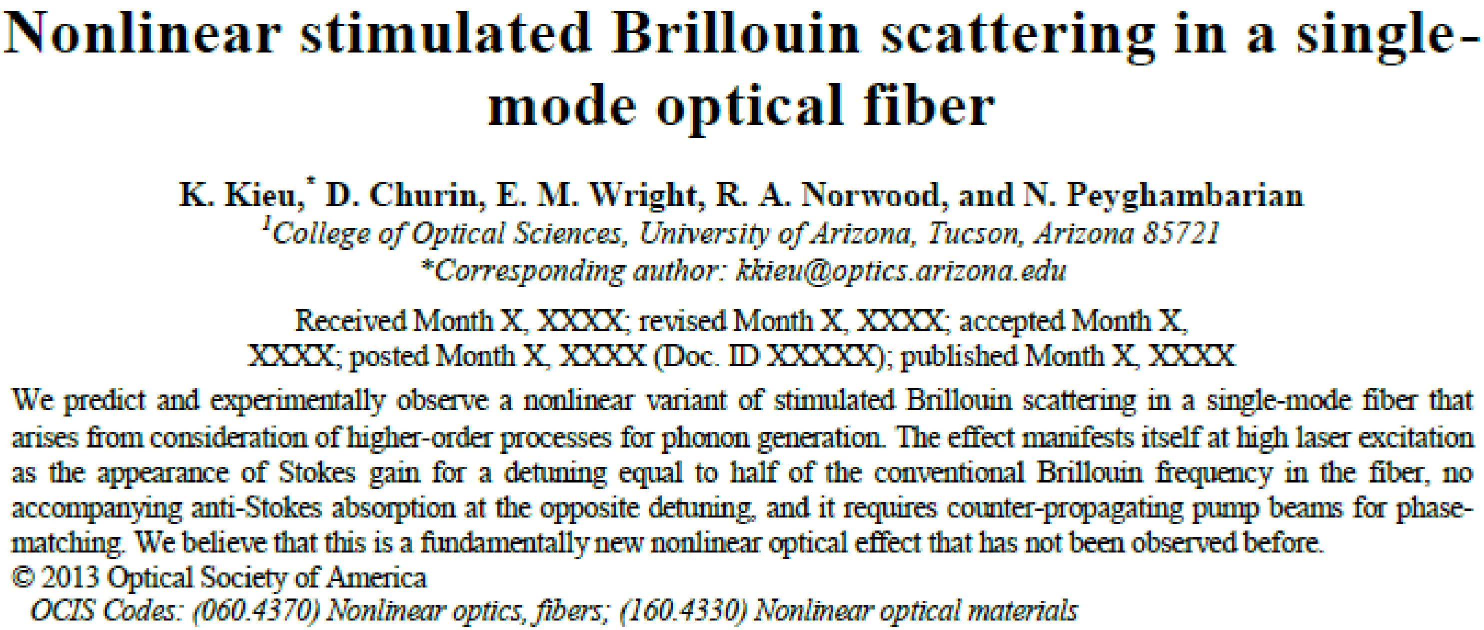
Scattering is one of the fundamental processes in light-matter interaction. There is no frequency shift in elastic light scattering (e.g., Rayleigh scattering), but there is a frequency shift when the scattering process is inelastic. The location, bandwidth, and shape of the frequency shifted scattered light normally contains information about the interactions between the atoms or molecules within the medium. There are two main inelastic light scattering processes that are known: 1) Raman scattering- where the resonance(s) come(s) from the interaction of light with the chemical bond(s) between the atoms comprising the medium; 2) Brillouin scattering – where the resonance appears as the result of the interaction of

first experimental observations of SBS were done using liquids [14, 15], to the best of our knowledge, Brillouin lasing in a liquid filled optical fiber has not yet been reported. In this communication, we report the first observation of Brillouin lasing in an i-LCOF filled with CS_2. The liquid state of matter has some advantages compared to widely adopted optical fibers made of glass, such as much higher Brillouin gain cross-section and the possibility for extensive dynamical tuning of the Brillouin gain profile (by adjusting the liquid pressure or temperature, for example). We also expect i-LCOF to be a robust platform for various experiments in nonlinear optics and light-matter interaction.

Spring 2012

Advanced Projects

- Not required for the class- voluntary work



Nonlinear stimulated Brillouin scattering in a single-mode optical fiber

K. Kieu,* D. Churin, E. M. Wright, R. A. Norwood, and N. Peyghambarian
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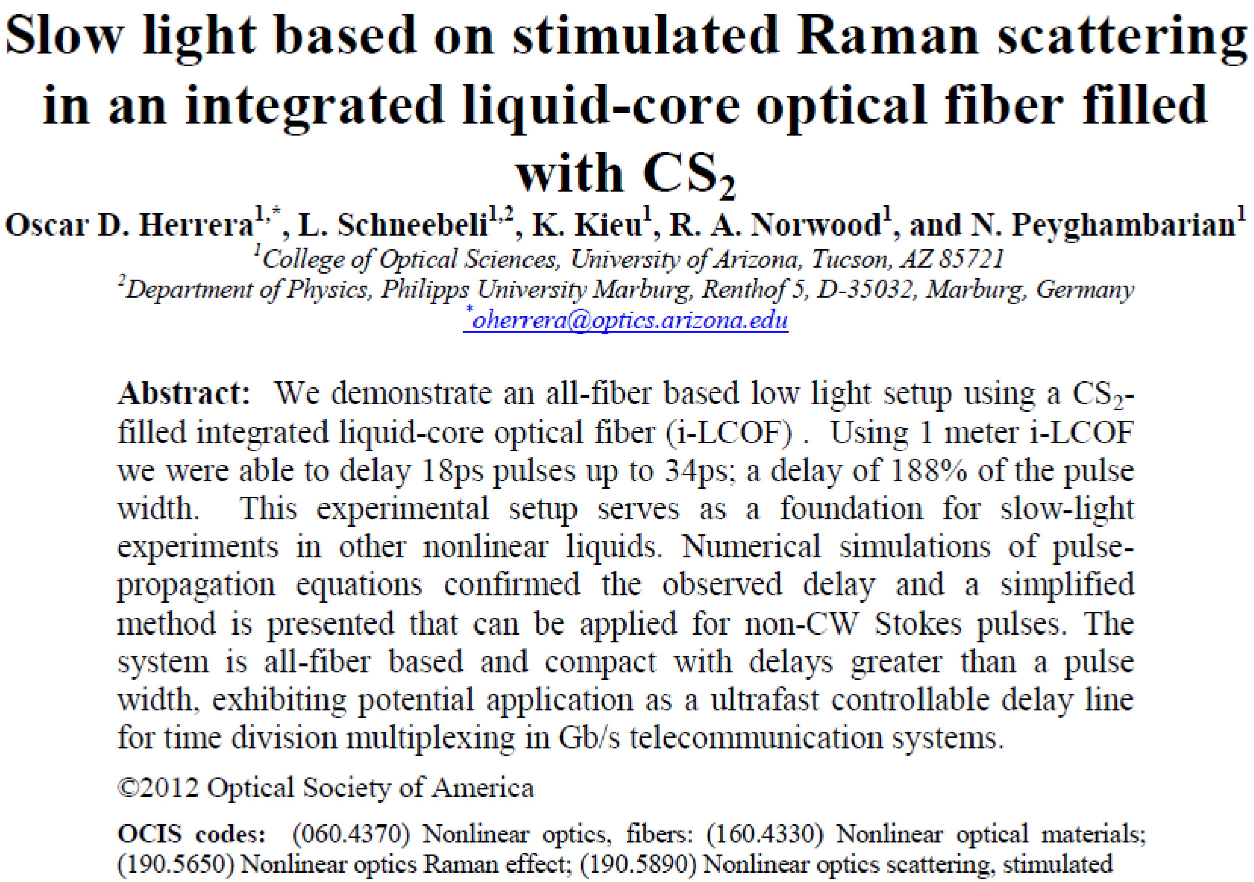
We predict and experimentally observe a nonlinear variant of stimulated Brillouin scattering in a single-mode fiber that arises from consideration of higher-order processes for phonon generation. The effect manifests itself at high laser excitation as the appearance of Stokes gain for a detuning equal to half of the conventional Brillouin frequency in the fiber, no accompanying anti-Stokes absorption at the opposite detuning, and it requires counter-propagating pump beams for phase-matching. We believe that this is a fundamentally new nonlinear optical effect that has not been observed before.

OCIS Codes: (060.4370) Nonlinear optics, fibers; (160.4330) Nonlinear optical materials

Spring 2013

Advanced Projects



Slow light based on stimulated Raman scattering in an integrated liquid-core optical fiber filled with CS_2

Oscar D. Herrera[1,*], L. Schneebeli[1,2], K. Kieu[1], R. A. Norwood[1], and N. Peyghambarian[1]
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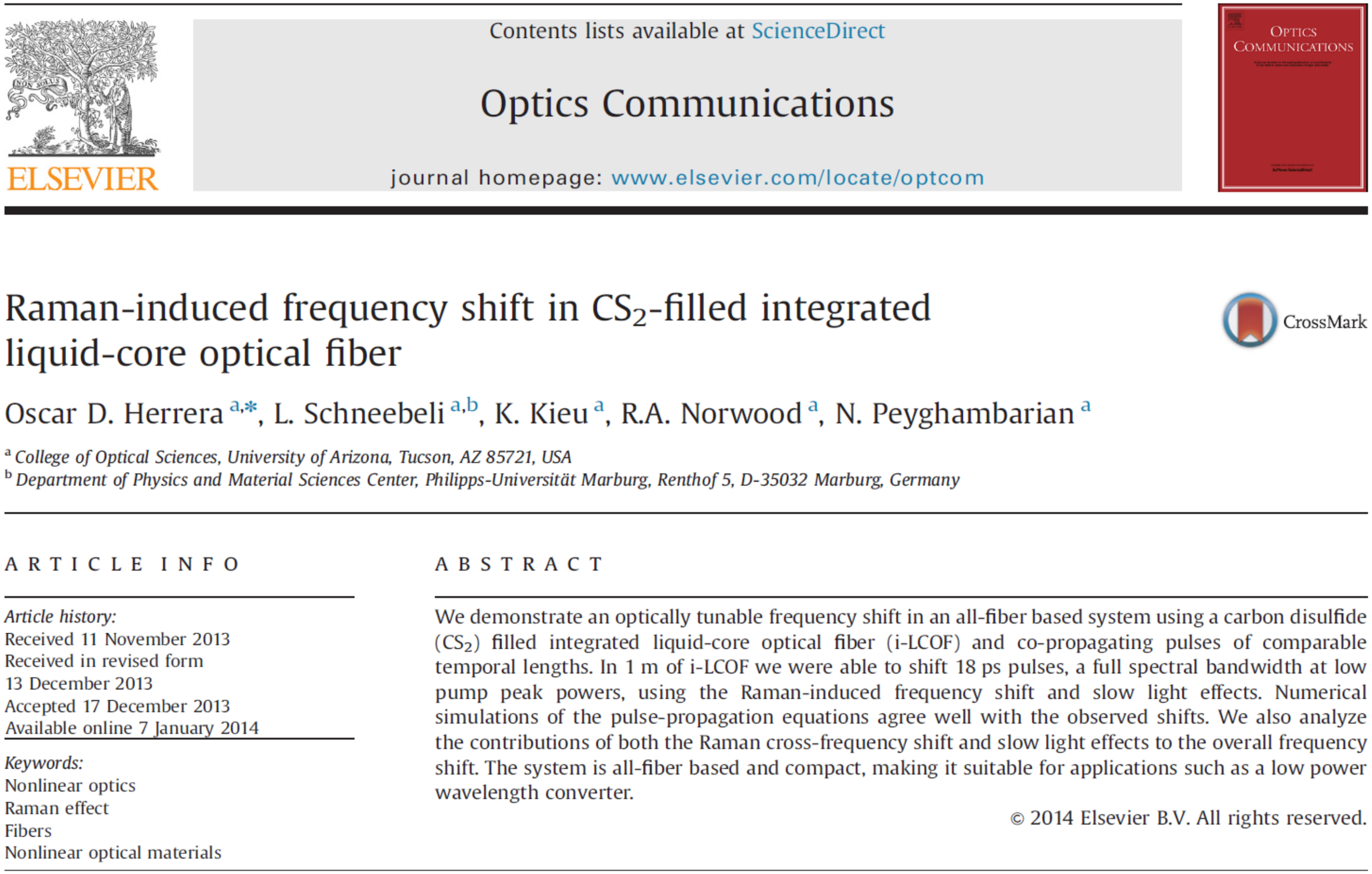
[2]*Department of Physics, Philipps University Marburg, Renthof 5, D-35032, Marburg, Germany*
[*]*oherrera@optics.arizona.edu*

Abstract: We demonstrate an all-fiber based low light setup using a CS_2-filled integrated liquid-core optical fiber (i-LCOF) . Using 1 meter i-LCOF we were able to delay 18ps pulses up to 34ps; a delay of 188% of the pulse width. This experimental setup serves as a foundation for slow-light experiments in other nonlinear liquids. Numerical simulations of pulse-propagation equations confirmed the observed delay and a simplified method is presented that can be applied for non-CW Stokes pulses. The system is all-fiber based and compact with delays greater than a pulse width, exhibiting potential application as a ultrafast controllable delay line for time division multiplexing in Gb/s telecommunication systems.

OCIS codes: (060.4370) Nonlinear optics, fibers: (160.4330) Nonlinear optical materials; (190.5650) Nonlinear optics Raman effect; (190.5890) Nonlinear optics scattering, stimulated

Oscar took the class in spring 2011

Advanced Projects



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Raman-induced frequency shift in CS_2-filled integrated liquid-core optical fiber

Oscar D. Herrera [a,*], L. Schneebeli [a,b], K. Kieu [a], R.A. Norwood [a], N. Peyghambarian [a]

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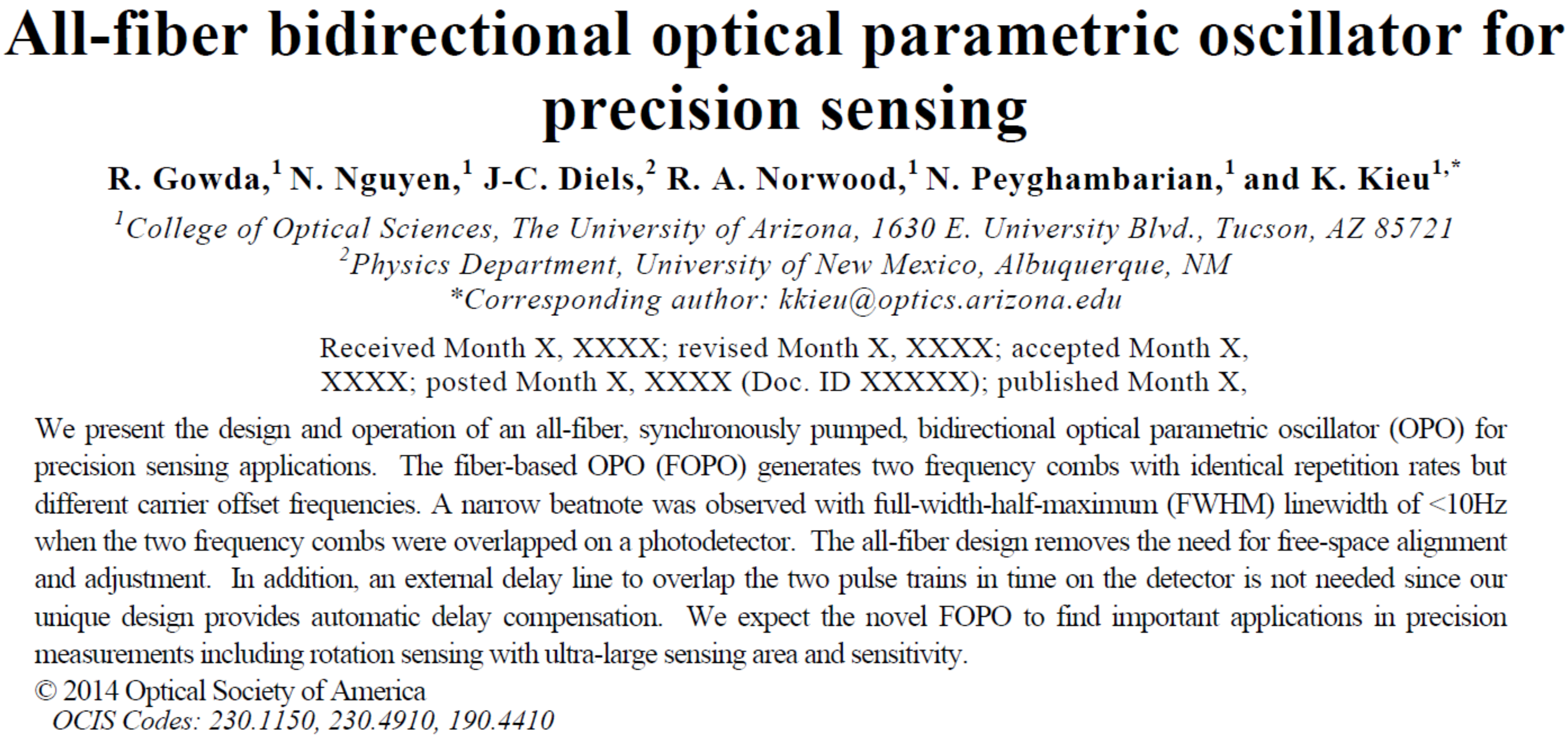
ABSTRACT

We demonstrate an optically tunable frequency shift in an all-fiber based system using a carbon disulfide (CS_2) filled integrated liquid-core optical fiber (i-LCOF) and co-propagating pulses of comparable temporal lengths. In 1 m of i-LCOF we were able to shift 18 ps pulses, a full spectral bandwidth at low pump peak powers, using the Raman-induced frequency shift and slow light effects. Numerical simulations of the pulse-propagation equations agree well with the observed shifts. We also analyze the contributions of both the Raman cross-frequency shift and slow light effects to the overall frequency shift. The system is all-fiber based and compact, making it suitable for applications such as a low power wavelength converter.

Oscar took the class in spring 2011

Advanced Projects



All-fiber bidirectional optical parametric oscillator for precision sensing

R. Gowda,[1] N. Nguyen,[1] J-C. Diels,[2] R. A. Norwood,[1] N. Peyghambarian,[1] and K. Kieu[1,*]

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[2] *Physics Department, University of New Mexico, Albuquerque, NM*
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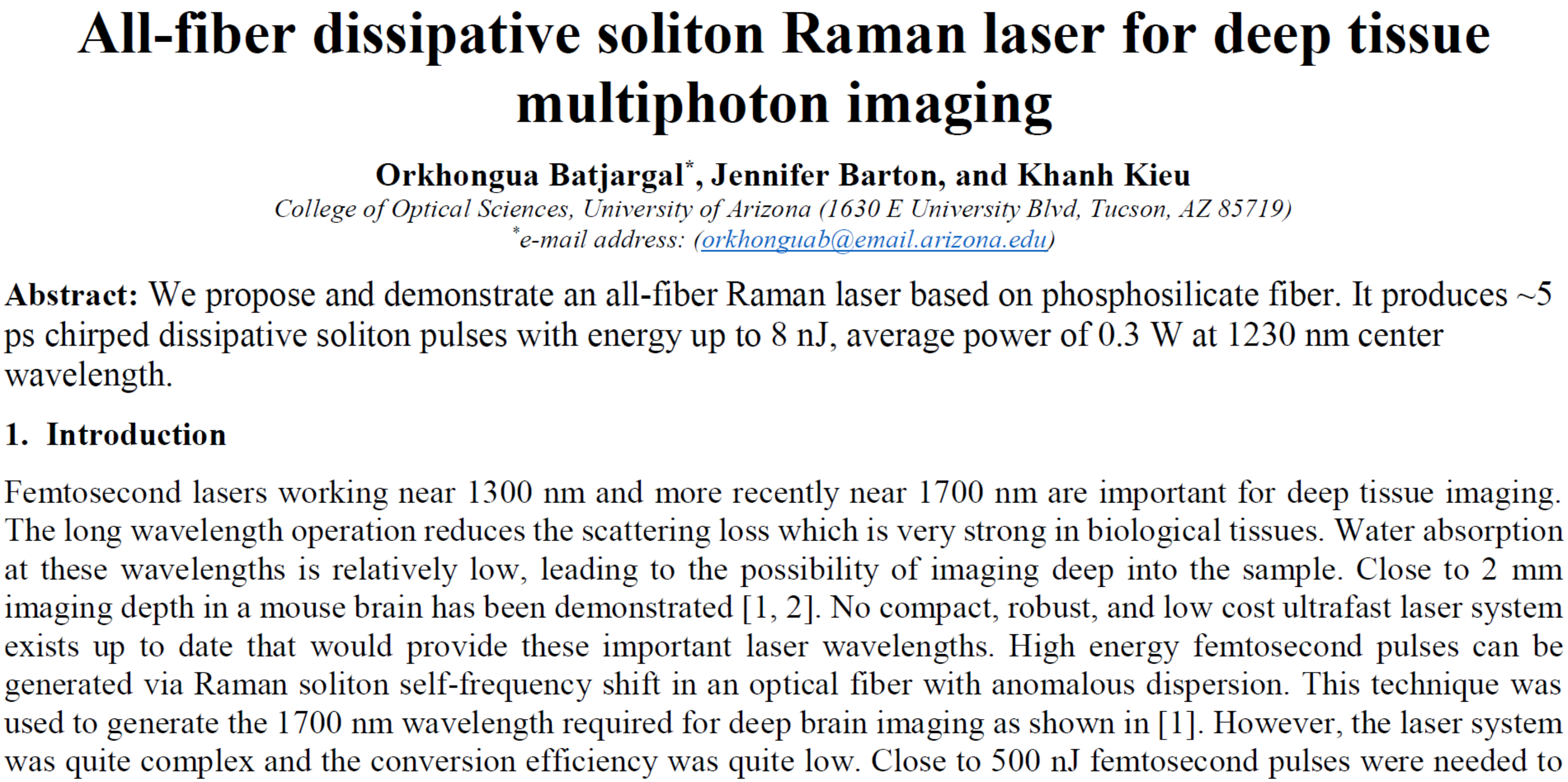
We present the design and operation of an all-fiber, synchronously pumped, bidirectional optical parametric oscillator (OPO) for precision sensing applications. The fiber-based OPO (FOPO) generates two frequency combs with identical repetition rates but different carrier offset frequencies. A narrow beatnote was observed with full-width-half-maximum (FWHM) linewidth of <10Hz when the two frequency combs were overlapped on a photodetector. The all-fiber design removes the need for free-space alignment and adjustment. In addition, an external delay line to overlap the two pulse trains in time on the detector is not needed since our unique design provides automatic delay compensation. We expect the novel FOPO to find important applications in precision measurements including rotation sensing with ultra-large sensing area and sensitivity.

OCIS Codes: 230.1150, 230.4910, 190.4410

Roopa took the class in spring 2012

Advanced Projects



All-fiber dissipative soliton Raman laser for deep tissue multiphoton imaging

Orkhongua Batjargal[*], **Jennifer Barton, and Khanh Kieu**
College of Optical Sciences, University of Arizona (1630 E University Blvd, Tucson, AZ 85719)
[*]*e-mail address: (orkhonguab@email.arizona.edu)*

Abstract: We propose and demonstrate an all-fiber Raman laser based on phosphosilicate fiber. It produces ~5 ps chirped dissipative soliton pulses with energy up to 8 nJ, average power of 0.3 W at 1230 nm center wavelength.

1. Introduction

Femtosecond lasers working near 1300 nm and more recently near 1700 nm are important for deep tissue imaging. The long wavelength operation reduces the scattering loss which is very strong in biological tissues. Water absorption at these wavelengths is relatively low, leading to the possibility of imaging deep into the sample. Close to 2 mm imaging depth in a mouse brain has been demonstrated [1, 2]. No compact, robust, and low cost ultrafast laser system exists up to date that would provide these important laser wavelengths. High energy femtosecond pulses can be generated via Raman soliton self-frequency shift in an optical fiber with anomalous dispersion. This technique was used to generate the 1700 nm wavelength required for deep brain imaging as shown in [1]. However, the laser system was quite complex and the conversion efficiency was quite low. Close to 500 nJ femtosecond pulses were needed to

Orkhongua took the class in spring 2017

Advanced Projects

Not required for the class: voluntary work

Possible topics:

- Bidirectional Brillouin Fiber Laser
- Fiber Optical Parametric Oscillator
- Difference Frequency Generation
- High Energy, High Peak Power Fiber Lasers
- …

Other Topics

- What a student needs to do before getting a Ph.D.?
- How to write a peer-reviewed journal paper?
- How much a graduate student cost?
- What are the journals in optics that you should read regularly?
- Students from Harvard, MIT, Cornell: what is the difference?

Final Presentation

1. Ajay Gautham Manicka Sureshbabu, **“Testbed related activities in optical communication and networks”**
2. Nasrin Ghanbari, **“Surface plasmon resonance fiber sensors for real-time and label-free monitoring of cellular behavior”**
3. Chen-Ting Liao, **"Transient Absorption Spectroscopy in Helium Probed by Attosecond Pulse Trains"**
4. Hui-min Leung, **“Cancer imaging”**
5. Neil Ou, **“Nano-fabrication by Electron Beam Lithography”**
6. Renyuan Zhang, **“Laser applications”**
7. Michael Gehl, **“Molecular Beam Epitaxy”**
8. Wenbo Gao, **“Numerical analysis of spectra from optical and electrical spectrum analyzers”**
9. Raj Patil, **“Polarization dependent color switching by extra-ordinary transmission in H-slit plasmonic metasurface”**
10. Babak Amirsolaimani, **“Multi-photon microscopy”**
11. Xiaole Sun, **“Free-space optical communication”**
12. Jilin Yang: **“Phase contrast microscope”**
13. Likun Lin: **“The introduction to Software-Defined Networking (SDN)”**
14. Patrick Keiffer: **“Quantum biology, how birds may be using quantum effects to navigate by magnetic fields”**
15. Samantha L. White: **“Quantum dots for imaging the brain”**

Organization and schedule

- Lecture on Fridays at 11am (Meinel, Room 432)
- Lab work ~2-3 hours a week (Meinel, Room 436)
- Report due before new project starts
- Divide into 2 groups of 3, set up lab time for each group