



## PIC Sensors: About the Course

### Intro Video:

<https://youtu.be/GBaahiap0kc>

### Syllabus:

- Description of Course:

Have you wondered about how a PIC sensor works? This new course covers the basics of photonics chem-bio sensing components and techniques. This will provide learners with insights that will lay the foundation for them to envision their own PIC sensors. They will learn to make judicious decisions regarding wavelengths, materials platforms, light sources, spectrometers, and photodetector solutions based on their desired application. The course includes a diverse line-up of invited lectures with leading-edge PIC sensor experts from around the world, who review critical metrics for designing photonics sensing systems.

- Outline:

Topic 1: Introduction to PIC sensors

Topic 2: PIC sensing system overview Topic 3: Sensing element design

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Topic 4: Light source

Topic 5: Detector

Topic 6: Spectrometer

Topic 7: Integrated photonic biosensing Topic 8: Markets, roadmap, and sensors PDK

- Prerequisites:

Basic knowledge of guided-wave optics

- Learning Outcomes:

The students will learn about the methods used in integrated photonic sensing with their respective figures of merit, such that they will be able to select a method for a particular application. They will gain knowledge of the working principles and key metrics of the different components involved in a PIC sensing system, to allow them to design their own PIC for sensing.

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- Grading Policy:

A mix of numerical and multiple-choice questions are asked after each lecture or block of lectures. Students have 2 attempts to validate the lecture (resp. block of lectures) by answering 60% of the questions correctly. Every single set of questions must be validated to pass the class.

- Contact Information:

Office Hours: Fridays 12-1 pm

The teaching staff can be reached at [picsensors@mit.edu](mailto:picsensors@mit.edu) for logistical questions about the course.

Questions related to the course content can be asked in the class forum.

This course is led by Prof. Juejun Hu and Dr. Anu Agarwal, with 9 guest lecturers.

- Duration:

12 hours of video lectures

Suggested duration: 6 weeks, asynchronous

- Tuition:

\$99 per student

### **Prof. Juejun Hu**



Prof. Juejun (JJ) Hu is currently an Associate Professor at MIT's Department of Materials Science and Engineering. His research primarily focuses on integrated optics and photonics. Prof. Hu has authored and coauthored more than 100 refereed journal publications. He has been recognized with the SPIE Early Career Achievement Award, the Robert L. Coble Award from the American Ceramic Society, the

Vittorio Gottardi Prize from the International Commission on Glass, the NSF CAREER award, and the DARPA Young Faculty Award, among others.

**Dr. Anu Agarwal**



Dr. Anu Agarwal is currently a Principal Research Scientist at MIT's Department of Materials Science and Engineering and. She is developing integrated Si-CMOS compatible linear and non-linear materials for photonic devices, especially in the mid-IR regime, for hyperspectral imaging and chem-bio sensing. She has over 200 journal and refereed conference publications, 22 awarded patents and 4 pending patents. She also serves as the Leader of the AIM Academy Laboratory for Education and Application Prototypes (LEAP) at MIT.

**Dr. Shrenik Deliwala**



Shrenik Deliwala received his Ph. D. in Physics from Harvard University in 1995 and since then he has worked on photonics products ranging from precision interferometry to silicon photonics to consumer-level optical sensors. His work experience includes advanced sensor and light-matter interactions research at Science Research Laboratory Inc.; founder and CTO at a telecommunication start-up OptronX Inc., where he invented a silicon modulator, which later morphed into LightWire acquired by Cisco; and creating and productizing many new photonics products at Analog Devices, Inc., such as photonics-based sensing for medical and environmental monitoring, where a substantial effort has been devoted to commercializing and making affordable, high-volume gas sensing products in the midwave infrared region to monitor our environment, which will make an impact in reducing GHG emissions.

### **Dr. Sergio Nicoletti**



Dr. Sergio Nicoletti received the Ph.D. degree in 1996 working on HTc superconducting devices. From 1997 he was with CNR-IMM (Italy) working on Smart Sensors/Systems for air quality monitoring and from July 2002 he was in charge of the management of the Sensor Group at the Bologna division. In 2004, he took a visiting scientist position at HGST in San Jose, CA, USA, working on magnetic recording heads devices. In 2006, Sergio joined CEA-LETI to work on optical sensing devices for chemical detection first as project manager and subsequently as business developer in charge of the industrial partnership. Since then, he was involved in several industrial and collaborative projects now in the portfolio of this activity. His publication track includes more than 20 patents and more than 100 publications in peer-reviewed journals. Since 2016 he is the director of the MIRPHAB pilot line and coordinator of the H2020 related project.

### **Prof. Delphine Marris-Morini**



After defending her PhD in 2004, Prof. Delphine Marris-Morini became first assistant professor in 2005 and then full Professor in 2015 at Paris Sud University (now Paris-Saclay University). She developed her research towards active devices in silicon photonics including high speed optical modulators and Ge/SiGe Quantum well modulators. She received an ERC starting grant (INSPiRE) on Ge-rich photonic integrated chips towards the mid-IR wavelength range for sensing and spectroscopic application, which allow the demonstration of world's premieres such as the first all optical modulation in Ge- based waveguide in the deep mid-IR wavelength up to 11  $\mu\text{m}$ , or the first 2 octave on-chip supercontinuum generation from 3 to 12  $\mu\text{m}$  wavelength. She was in charge of the silicon photonics group of the C2N from 2015 to 2020. She was nominated as a junior member of the Institut Universitaire de France in

2013, and she received the bronze medal from CNRS in 2013. She received the Prix Fabry-de Gramont from the French optical Society in 2017. She published over 100 journal papers.

#### **Dr. Christian Pfluegl**



Dr. Christian Pfluegl received his PhD in Electrical Engineering in 2005 from the Vienna University of Technology, Austria and his MS in Applied Physics from the University of Regensburg, Germany in 2002. From 2006 to 2010, he worked as a Research Associate at Harvard University in the group of Prof. Federico Capasso. His PhD and postdoctoral work focused on the development of Quantum Cascade Laser (QCL) technology and QCL-based instrumentation and led to several high-profile collaborations with world-renowned industrial partners. Dr. Pfluegl has authored or coauthored more than 60 technical papers and more than 100 conference proceeding papers/presentations. He has also authored or co-authored numerous granted and provisional patents. In 2010, he co-founded Pendar Technologies where he oversees the development and commercialization of QCL technology.

#### **Dr. Jerry R. Meyer**



Dr. Jerry R. Meyer received a Ph.D. in physics from Brown University in 1977. Since then he has carried out basic and applied research at the Naval Research Laboratory in Washington DC, where he is the Navy Senior Scientist for Quantum Electronics (ST). His research has focused on semiconductor optoelectronic materials and devices, especially new classes of lasers and detectors for the infrared. Dr. Meyer is a Fellow of the Optical Society of America (OSA), the American Physical Society (APS), the Institute of Physics (IOP), the Institute of Electrical and Electronics Engineers (IEEE), and SPIE. He is a recipient of the Presidential Rank Award (2016), ONR's Captain Robert Dexter Conrad Award for Scientific Achievement (2015), NRL's E. O. Hulbert Annual Science Award (2012), the IEEE Photonics Society Engineering Achievement Award (2012), the Dr. Dolores M. Etter Top Navy Scientists and Engineers of the Year Award (2008), and the NRL Edison Chapter Sigma Xi Award for Pure Science (2003). He has coauthored more than 390 refereed journal articles that have been cited more than 27,000 times (H-Index of 65), one book (Bands and Photons in III-V Semiconductor Quantum Structures,

Oxford University Press, 2021), 39 patents granted, and more than 190 Invited, Plenary, Keynote, and Tutorial conference presentations.

**Dr. Laurent Vivien**



Dr. Laurent Vivien is a CNRS researcher at the Center for Nanoscience and Nanotechnology (C2N) working on the development of fundamental concepts for silicon photonics including optoelectronic and hybrid photonic devices. His team was among the first to demonstrate high-speed waveguide germanium photodetectors and silicon modulators, in collaboration with CEA-Leti and STMicroelectronics. Dr Vivien has also been at the forefront of the development of hybrid integration of carbon nanotubes on Si photonics platform and on high-speed Pockels effect in strained silicon waveguides. He has published over 450 international peer-reviewed journal and conference papers, holds 8 patents and has supervised > 20 PhD and 10 post-docts. As a leading expert in silicon photonics, Dr Vivien is regularly invited to prestigious international conferences (over 180 invited presentations) including plenary, tutorial and keynote talks. In 2015, he received a Consolidator European Research Council (ERC) grant. He is also an elected Fellow of the Optical Society of America (OSA) and of the European Optical Society (EOS). He regularly serves as a Chair or a program committee member of EOS, OSA, IEEE and SPIE conferences on photonics and optoelectronics.

**Prof. Jifeng Liu**



Dr. Jifeng Liu received the B.S. and M. S. degrees in materials science and engineering from Tsinghua University, Beijing, China, and the Ph.D. degree in materials science and engineering from the Massachusetts Institute of Technology. He is currently an Associate Professor and the Materials Science and Engineering Program Lead at the Thayer School of Engineering, Dartmouth College. His major research field is photonic materials and devices, including integrated photonics for ultralow energy photonic datalinks as well as nanomaterials and nanostructures for photodetectors, image sensors, modulators and solar energy harvesting. He has authored or coauthored more than 80 peer-reviewed journal papers, more than 60 conferences papers, and six book chapters, which have been cited over 10,000 times according to Google Scholar. Dr. Liu has also been granted 15 U.S. patents related to

nanophotonic materials and devices. He is a recipient of NSF CAREER Award, a Fellow of the Optical Society of America (OSA), and a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE).

**Prof. Benjamin Miller**



Prof. Benjamin Miller completed his undergraduate studies at Miami University (Ohio), receiving degrees in Chemistry (B.S.), Mathematics (A.B.), and German (A.B.) in 1988. He next moved to Stanford University, where he carried out his Ph. D. research in Chemistry under the direction of Paul Wender. Following a stint as an NIH postdoctoral fellow at Harvard in Stuart Schreiber's laboratory, he joined the University of Rochester faculty in 1996, where he is currently Dean's Professor of Dermatology, Biochemistry and Biophysics, Biomedical Engineering, and Optics. His group's expertise in molecular recognition, combinatorial chemistry, nanotechnology, and optical sensing has been applied to the development of novel optical biosensor platforms, and synthetic compounds targeting RNAs involved in several human diseases. He is a Fellow of the OSA, AIMBE, and AAAS. Miller is a founder of Adarza BioSystems, Inc., a multiplex optical biodetection company located in St. Louis, MO. He is also the Academic Lead for Integrated Photonic Sensors in AIM Photonics.

**Dr. Kevin McComber**



Dr. McComber is the CEO and co-founder of Spark Photonics, a US-based photonics design house focused on developing the domestic photonics ecosystem. Prior to founding Spark Photonics, Dr. McComber worked in semiconductor manufacturing, healthcare, financial services, and most recently in higher education as the assistant director of AIM Photonics Academy at MIT. He holds a PhD in materials science and engineering from MIT.