Nonlinear nanophotonics for visible-emission lasers

Scott B. Papp[1,2]

[1]Time and Frequency Division, National Institute of Standards and Technology, Boulder, Colorado/USA
[2]Department of Physics, University of Colorado, Boulder, Colorado/USA

Email: scott.papp@nist.gov

Many laser applications require access to specific wavelength bands. For example, optical-atomic clocks provide a leap in performance for critical sensing and communication applications, but they demand compact lasers at wavelengths spread across the visible and near infrared. Integrated photonics enables high-performance, scalable laser platforms, however customizing laser gain to support wholly new bands is challenging and often prohibitively mismatched in scale to quantum-based sensing and information systems. We describe the research project nonlinear nanophotonics for visible-emission lasers enabled by heterogeneous integration with tantalum pentoxide (tantala), nonlinear wavelength converters, periodically poled lithium niobate, and a 980 nm pump laser.

Integrated photonics, especially through heterogeneous combinations of materials, supports a diverse range of functionalities from narrow linewidth lasers, high-speed modulation and photodetection, dense and scalable routing and distribution of photonic modes, and complex, interconnected system blocks[1]. Integrated photonics drives forward quantum sensing, high-speed optical data links, and photonic computing acceleration[2]. For tabletop and full laboratory systems, especially optical clocks and quantum sensors, heterogeneously integrated photonics has the potential to reduce the complexity of current free-space and fiber laser systems. However, the cost and complexity of development in heterogeneous lasers slows the process of porting them outside wavelength bands like 1550 nm, 1300 nm, and 980 nm in which significant investment is present. In this paper, we describe the Nonlinear Nanophotonics for Visible-Emission Lasers platform based on the concept of laser integration for one wavelength, eg. 980 nm, and nonlinear conversion across the 400 nm to 1550 nm range.

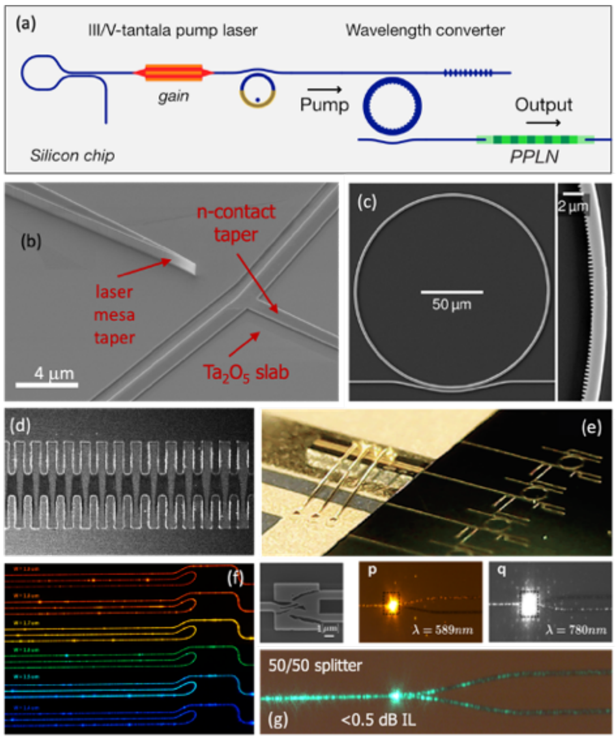

Fig. 1: Visible laser and integrated-photonics platform and device demonstrators. (a) Block diagram with heterogeneous integration of III/V laser gain and periodically poled lithium niobate with tantala. (b) Images of the laser taper structure between III-V and tantala layers. (c) High Q tantala microresonators. (d) Periodic poling of LN layers. (e) Nonlinear optical isolators and hybrid laser integration. (f) Tantala waveguides in the visible. (g) Inverse-design photonics with tantala for widely varying functionalities.

[1] D. T. Spencer et al., *An Optical-Frequency Synthesizer Using Integrated Photonics*, Nature **557**, 7703 (2018).

[2] T. Komljenovic, M. Davenport, J. Hulme, A. Y. Liu, C. T. Santis, A. Spott, S. Srinivasan, E. J. Stanton, C. Zhang, and J. E. Bowers, *Heterogeneous Silicon Photonic Integrated Circuits*, J. Lightwave Technol. **34**, 20 (2016).