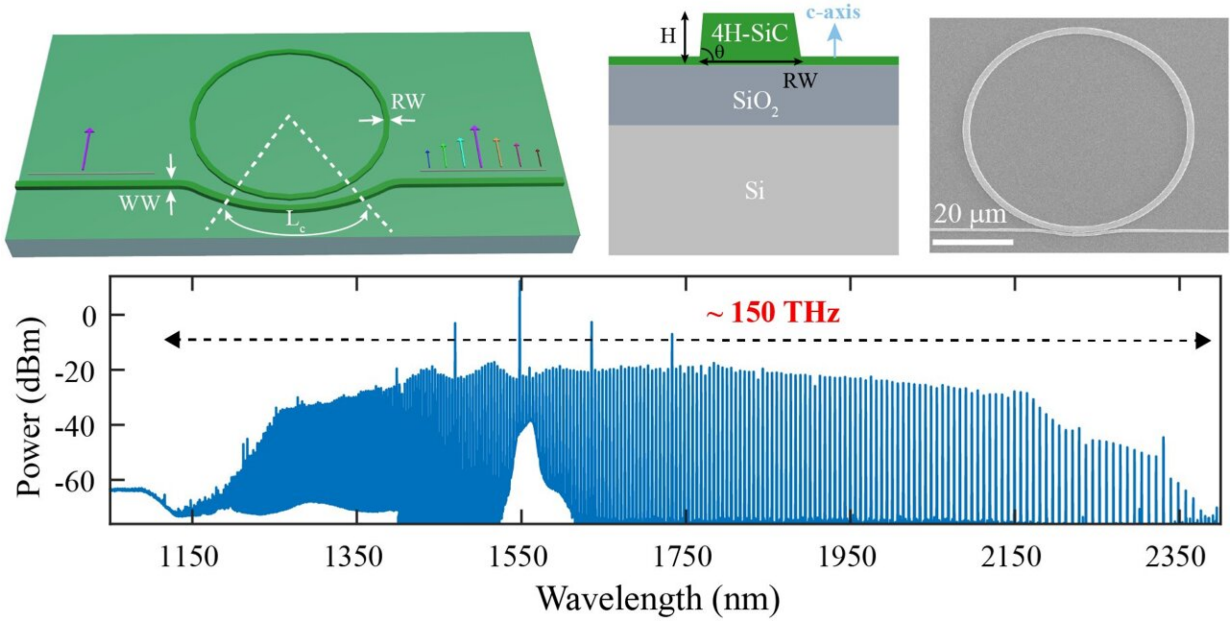
A chip-scale broadband light source in silicon carbide

March 18 2022, by Krista Burns



(a) Schematic top view (left) and cross section (right) of the 4H-silicon-carbide-on-insulator platform for frequency comb generation based on compact microring resonators. The sidewall angle (θ) is estimated near 80–85 deg in our nanofabrication. Dispersion engineering is carried out by varying the ring waveguide width (RW). In addition, efficient coupling is realized using the pulley structure where the access waveguide width and coupling length are adjusted to achieve phase matching to the desired resonant mode families. (b) Scanning electron micrograph of a 36-μm-radius SiC microring. In this work, the SiC thickness is fixed at 500 nm with a pedestal layer of 50 nm. (c) Simulated integrated dispersion [Dint; see its definition in Eq. (1)] for the fundamental transverse-electric (i.e., TE00) mode with ring widths varied from 1.6 μm to 1.9 μm (solid lines). For comparison, Dint for the fundamental transverse-magnetic (i.e., TM00) mode is also provided for the ring width of 1.9 μm (magenta dashed line), exhibiting much larger values than those of the TE00 modes. (d) Simulated comb spectrum for the TE00 mode for a 36-μm-radius SiC microring with RW 1.8 μm and an input power of 100 mW, featuring a spectral bandwidth of more than one octave and dispersive-wave generation near the wavelength of 1150 nm. In the simulation, the Kerr nonlinear parameter is assumed to be $\gamma \approx 2.1$ W−1 m−1, and the intrinsic and loaded quality factors are assumed to be 1.25 million and 0.75 million, respectively. Credit: *Photonics Research* (2022). DOI: 10.1364/PRJ.449267

Optical frequency combs have changed science and technology as we know it. Responsible for measuring things like infrared and ultraviolet light, greenhouse gases, atomic clocks, and disease, optical frequency combs act as rulers that measure light. By combing through light, or frequencies, this technology can focus on specific frequencies that researchers can separate and study in limitless situations.

These important and powerful combs are made up of hundreds of individual comb lines that are coherent with each other. Traditionally demonstrated in optical fibers or nonlinear crystals, a research team in Carnegie Mellon University's Department of Electrical and Computer Engineering has recently demonstrated a chip-scale broadband light source in silicon carbide, which has been traditionally used as an abrasive or for electronic devices that operate at high temperatures or high voltages.

The team, led by Qing Li, assistant professor of electrical and computer engineering, used the advanced facilities in the Claire & John Bertucci Nanotechnology Laboratory to create miniaturized optical devices that are less than 0.1 mm in size, approximately the equivalent to the thickness of one sheet of paper.

Silicon carbide recently emerged as a promising candidate due to its unique properties, including possessing strong second- and third-order nonlinear coefficients and hosting various color centers that can be utilized for a wealth of quantum applications.

"The fabrication process has been carefully optimized to define tiny ring-type structures with smooth surfaces," states Li. "Light confined in these so-called microrings experiences significant power enhancement due to the resonance effect, which is strong enough to induce an optical nonlinear response called the Kerr effect."

As a result, with an input laser being a single wavelength near 1550 nm, the output light consists of multiple wavelengths spanning 1150 nm to 2400nm. Because the composite frequency lines are discrete and equally spaced, this special type of light is termed as an optical comb.

In the past decade, miniaturizing the optical comb technology using chip-scale device platforms attracted a lot of research efforts, which can significantly reduce its size, weight, and power consumption, all of which are critically important for its broader adoption in practical applications. In the United States, funding agencies such as DARPA played a key role in driving this direction.

"This work is the first demonstration of such wideband combs in silicon carbide, proving its competitiveness as an efficient nonlinear material against more commons choices such as silicon and silicon nitride," explained Li. "Our goal is to develop a series of device technologies, including frequency generation, modulation and conversion, and combine them with the quantum technologies implemented in the silicon carbide platform in a seamless fashion."

This will eventually lead to powerful information processors that can handle classical and quantum information simultaneously, all based on silicon carbide.

The research work was carried out by postdoctoral researcher Dr. Lutong Cai, and graduate students Jingwei Li and Ruixuan Wang. The paper was published in *Photonics Research*.

More information: Lutong Cai et al, Octave-spanning microcomb generation in 4H-silicon-carbide-on-insulator photonics platform, *Photonics Research* (2022). DOI: 10.1364/PRJ.449267

Provided by Carnegie Mellon University Electrical and Computer Engineering