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Optical Frequency Combs

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Optical frequency combs have made a revolution in optical frequency metrology. Deployment of microstructured fibers that maintain single-mode operation over extended wavelength range, together with unique dispersion properties, has allowed compression of the pulses from mode-locked titanium sapphire lasers and produced octave-spanning frequency combs. Subsequently phase-locking the optical frequency to the pulse repetition rate has allowed drastic simplification of the direct measurement of optical frequency, and also the transfer of metrological frequency stability between different optical frequencies and between optical and radio frequency domains. In the past decade, a whole variety of measurement methods and devices have been developed that are based on generation of optical frequency combs and coherent nonlinear interactions, assisting in development of optical frequency standards, high-resolution spectroscopy, elaborate time domain, and high-productivity spectroscopic measurements.

The original toolkit of optical frequency combs—powerful pulsed lasers and microstructured fiber as a nonlinear interaction medium—has been in recent years complemented by the development of radio-frequency photonic methods and devices. Originally utilizing electro-optical modulators, fiber loops, and high-speed photodetectors for generation, distribution, and processing of high-spectral high-frequency microwave signals, these methods have recently benefitted from deployment of high-finesse microcavities with whispering-gallery modes. Very high quality factor and recirculation of light in these tiny cavities has allowed reduction of the power threshold of nonlinear interactions and observation of self-starting

optical frequency combs with the input optical power laying in the range of several milliwatt. Prospects are opened for “pocket metrology,” ultracompact optical clocks for GPS-denied applications, miniature low-noise microwave signal sources, and advanced sensing.

This special section contains eight papers that represent different approaches and aspects of optical frequency comb techniques, from solid-state mode-locked lasers, through their applications in nonlinear frequency conversion and metrology, to generation of optical combs in recirculating modulator schemes, and high data rate transmission. Three papers represent recent results on generation of optical frequency combs in crystalline microcavities with whispering-gallery modes.

Vladimir Ilchenko received MS and PhD degrees in physics from Moscow State University, Russia, where he later continued as a staff researcher and an associate professor working on optical microcavities. In 1998 he joined the time and frequency group at NASA's Jet Propulsion Laboratory. Since 2001, he has been chief scientist at OEwaves, Inc., a company in Pasadena, California, that commercializes microwave photonics products. He is a fellow of SPIE and has co-chaired the SPIE Conference on Laser Resonators, Microresonators and Beam Control for many years. He has published over 100 peer reviewed articles and is inventor on 56 US patents.

Zhaohui Li obtained his BS in the Department of Physics and MSc in the Institute of Modern Optics from Nankai University, China, in 1999 and 2002, respectively, and his PhD from the Nanyang Technological University in 2007. He joined the Institute of Photonics Technology, Jinan University, China, as a professor in 2009. His research interests are optical communication systems, optical signal processing technology, and ultrafine measurement systems. He has over 100 publications in internationally refereed conferences and journals.