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(54) **METHOD AND APPARATUS FOR OPTICAL FREQUENCY COMB GENERATION USING A MONOLITHIC MICRO-RESONATOR**

6,591,026 B2 * 7/2003 Endo et al. 385/15
7,356,214 B2 * 4/2008 Ilchenko 385/15
2004/0100675 A1 * 5/2004 Matsko et al. 359/245
2005/0220411 A1 10/2005 Ilchenko

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FOREIGN PATENT DOCUMENTS

WO WO 2004107033 A1 * 12/2004
WO 2005/122346 12/2005

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OTHER PUBLICATIONS

Armani et al., “Ultra-high-Q toroid microactivity on a chip”, Nature, vol. 421, pp. 925-928 (2003).

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(51) **Int. Cl.**

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G02F 2/02 (2006.01)
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(57) **ABSTRACT**

An optical frequency comb generator includes a laser device arranged for generating input laser light having a predetermined input light frequency, a dielectric micro-resonator having a cavity exhibiting a third order nonlinearity, so that the micro-resonator is capable of optical parametric generation providing parametrically generated light, and a waveguide optically coupled to the micro-resonator, the waveguide being arranged for in-coupling the input laser light into the micro-resonator and out-coupling the parametrically generated light out of the micro-resonator, wherein the laser device, the waveguide and the micro-resonator being arranged for resonantly in-coupling the laser input light to a mode of the micro-resonator with a minimum power level so that an optical field inside the cavity exceeds a predetermined cascaded parametric oscillation threshold at which the parametrically generated light includes frequencies of frequency sidebands of the input light frequency and of the sidebands thereof.

(52) **U.S. Cl.** **359/330**; 372/32; 359/245

(58) **Field of Classification Search** 359/245, 359/326–332; 385/15, 28, 32, 50; 372/22, 372/32, 94, 105

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,201,638 B1 * 3/2001 Hall et al. 359/346
6,473,218 B1 10/2002 Maleki et al.

7 Claims, 9 Drawing Sheets

