EFFICIENT WAVELENGTH CONVERSION IN NOVEL INTEGRATED STRUCTURES

R. Morandotti[1], L. Razzari[1], M. Ferrera[1], D. Duchesne[1], M. Peccianti[1], A. Pasquazi[1], S. Chu[2], B.E. Little[2], D.J. Moss[3]

1. INRS-EMT, 1650 Boulevard Lionel Boulet, Varennes, Québec, Canada, J3X 1S2

Also with: Dipartimento di Elettronica, Università di Pavia, via Ferrata 1, 27100 Pavia, Italy

2. Infinera Corp, 9020 Junction Dr, Annapolis, Maryland, USA 94089

3. CUDOS, School of Physics, University of Sydney, New South Wales 2006 Australia

E-mail: corresponding.morandott@emt.inrs.ca

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Abstract

Up to date, the world of electronics has always been an inexhaustible source of resources to satisfy the continuous request for larger bandwidth in communication systems. Unfortunately the bit rate limit of electronic devices (around 50 Gb/s) will soon be reached, and scientists and engineers are now struggling for alternative solutions. Among them, all-optical signal processing appears to be one of the most viable since it brings the promise to drastically increase the performances of transmission networks and, at the same time, to keep the associated costs low. However, in order to fulfill the goal of realizing all-optical agile communications systems and improve overall all-optical devices performances, it is mandatory to optimally perform fundamental network operations such as optical switching, data storage, ultrafast modulation, etc.

In particular, wavelength conversion is required to realize wavelength division multiplexing systems capable of substantially increasing the bit rate by channeling the information on different frequency carriers. Recently ultra-low CW pump power (5 mW) wavelength conversion based on Four Wave Mixing (FWM) has been reported in silicon micro-ring resonators. Nevertheless, it is of paramount importance to study other material

systems, since silicon is well known to suffer from two-photon absorption (TPA) that in turn induces free carrier losses and may affect the performance of silicon based devices.

In this work we first demonstrated, by means of C-MOS compatible Hydex ® glass based micro ring resonators, efficient wavelength conversion by FWM using ultra-low continuous-wave pump power (<5 mW, @ 1553.38 nm). In this first set of experiments, we used rings whose Q factor was 65,000 and whose free spectral range was 575 GHz. By using the experimental value of the FWM efficiency we estimated the nonlinear refractive index (n2) of Hydex waveguides to be as much as five times larger than that of standard Silica, and the nonlinear γ parameter to be around 250 times higher than that of typical single mode glass fibers. Furthermore, the overall field enhancement factor of our device was shown to be $\cong 1.4\cdot 10^{7}$, much larger than in semiconductor structures where losses tend to be in the order of several dB/cm.

Our results are comparable to the highest values reported to date in silicon ring resonators, and in addition they combine the advantages of ultra-low optical loss (0.06 dB/cm) with the absence of two-photon absorption (near $\lambda = 1.5\mu m$). We believe that these achievements may bring us a step forward in the quest to create very efficient all optical communication networks.

Furthermore, the possibility of creating novel frequency at very affordable power levels could open up an host of different applications beyond their use in telecommunication networks. For example, integrated multiple wavelength laser sources may be considered of great importance for applications as high-precision broadband sensing and spectroscopy, molecular fingerprinting, optical clocks, and attosecond physics. Even if they have recently been demonstrated in silica and single crystal micro-toroid resonators using parametric gain, for applications in telecommunications and optical interconnects, analogous devices in a fully integrated, CMOS compatible platform still do not exist. While approaches such as silicon micro-ring resonators have been shown not to be ideal, other materials, such as Silicon nitride, have recently been proven to be a promising alternative platform for nonlinear optical devices since they exhibits negligible saturation effects due to multi-photon absorption, and this enabled the demonstration of efficient multi-wavelength optical parametric oscillation in integrated ring resonators.

In a second set of experiments, using rings with an higher Q factor, we succeeded in realizing a fully integrated, CMOS compatible, multiple wavelength source. We achieve CW optical “hyper-parametric” oscillation in a high quality factor (Q = 1.2 million) doped silica glass micro-ring resonator, with a differential slope efficiency above threshold of 7.4% for a single oscillating mode out of a single port, a CW threshold power as low as 54 mW, and a controllable range of frequency spacing from 200 GHz to more than 6 THz. The low loss, design flexibility, and CMOS compatibility of this device will enable multiple wavelength sources for telecommunications, computing, sensing, metrology and other areas.