Experimental Observation of Second Harmonic Generation Enabled by Longitudinal Components in Indium Gallium Phosphide Nanowires

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Novel integrated photonics platforms are having a large impact on nonlinear optics. The inherent strong confinement and highly nonlinear materials allow for ultra-efficient frequency conversion. Recent reports on second harmonic (SH) generation for example posted record conversion efficiencies in millimetre long waveguides [1,2]. These promising results predict an exciting future for frequency conversion in subwavelengths structures. Yet, the vectorial nature of waves propagating in high index contrast nanowaveguides is often overlooked. Here we demonstrate second harmonic generation enabled by the longitudinal component of both the pump and the second harmonic wave. We use a 680 nm wide, 320 nm thick Indium Gallium Phosphide nanowaveguide [3]. As in other III-V materials, only the $\chi^{(2)}_{xyz}$ component is nonzero. Previous demonstrations of second harmonic generation used waveguides that are rotated 45° in order to split the main transverse component along two axes [1,4]. Conversely, we use a 1.5 mm long waveguide whose propagation direction is aligned along the z crystallographic axis. The effective nonlinearity is hence proportional to the overlap integral $\int \chi^{(2)}_{xyz} \left(E_x^{*SH} E_y^F E_z^F + E_y^{*SH} E_x^F E_z^F + E_z^{*SH} E_x^F E_y^F\right) dxdy$ where $\vec{E}(x,y)$ is the spatial distribution of the electric field in the transverse plane. Full-vectorial simulations predict phase matching and a nonzero overlap between a fundamental quasi-transverse magnetic (TM) pump mode and a higher order SH TM mode around 1575 nm. Importantly, such conversion would not be permitted without strong longitudinal field components. The effective index of both the pump and SH as well as the different field components are shown in Fig. 1. As can be seen, most field components have nonnegligible amplitudes and hence contribute to the effective nonlinearity. We launch a 3 mW telecom band pump in our waveguide through a lensed fiber and collect the second harmonic by use of a high NA (0.9) objective. Our results are shown in Figure 1. We find a maximum conversion of 0.2 %/W/cm^2, around 2 orders of magnitude less that the theoretical prediction, indicating that the second harmonic mode likely suffers from strong propagation losses. Our experimental image of the SH mode confirms the excitation of an antisymmetric TM higher order mode. In conclusion we demonstrated second harmonic generation through mixing of transverse and longitudinal field components. Not only does it demonstrate the vector nature of the propagating waves, it also allows to excite higher order modes with different symmetries. Furthermore, full-vectorial simulations show that similar wave-mixing is the most efficient conversion scheme for waveguides fabricated in thick (>200nm) InGaP layers.

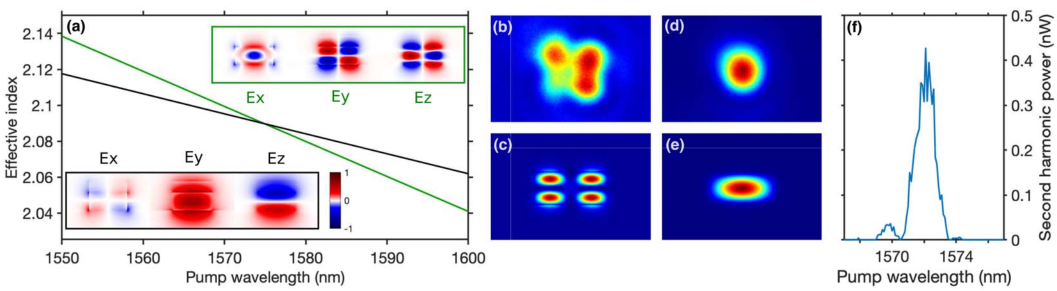

Fig. 1 (a) Simulation of the effective indices of a pump mode (black) and a SH mode (green). The spatial distribution of the different electric field components is shown as inset. (b-c) Measured and computed spatial distribution of the intensity of the SH at the output of the waveguide. (d-e) Measured and computed spatial distribution of the intensity of a 775 nm TM fundamental wave for comparison. The field of view for theoretical modes is 1.5 µm x 1 µm. (f) Second harmonic power collected at the output of the waveguide as a function of the pump wavelength.

References

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978-1-7281-0469-0/19/$31.00 ©2019 IEEE

Wednesday – Orals

ROOM 4a ICM

ED-4.3 WED 11:00

Precise Comb-Based Fourier Transform Spectroscopy for Line Parameter Retrieval

A.C. Johansson[1], L. Rutkowski[1,2], P. Maslowski[3], A. Filipsson[1], T. Hausmanninger[1], G. Zhao[1], O. Axner[1], and •A. Foltynowicz[1]; [1]Department of Physics, Umeå University, Umeå, Sweden; [2] Univ Rennes, CNRS, IPR (Institut de Physique de Rennes)-UMR 6251, Rennes, France; [3] Institute of Physics, Nicolaus Copernicus University in Torun, Torun, Poland

We perform high-precision measurements of entire molecular bands using direct and cavity-enhanced optical frequency comb Fourier transform spectroscopy and retrieve absorption line parameters with precision beyond the Voigt profile.

ED-4.4 WED 11:15

Broadband Optical Cavity Mode Measurements at Hz-Level Precision With a Comb-Based VIPA Spectrometer

G. Kowzan, D. Charczun, A. Cygan, R.S. Trawiński, D. Lisak, and •P. Masłowski; Institute of Physics, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University in Torun, Torun, Poland

We present cavity mode width and frequency measurements over 60-cm-1 range at Hz-level precision. We utilize a near-infrared frequency comb and a VIPA spectrometer to retrieve absorption and dispersion of a CO-N2 sample in a high-finesse cavity.

ROOM 4b ICM

EI-4.2 WED 11:00

Hot Electron Transfer In Graphene/WS2 Heterostructures

•C. Trovatello[1], G. Piccinini[2,3], S. Forti[2,3], F. Fabbri[2,3,4], C. Coletti[2,3,4], G. Cerullo[1,5], and S. Dal Conte[1]; [1]Politecnico di Milano, Milan, Italy; [2]Center for Nanotechnology Innovation @ NEST, Istituto Italiano di Tecnologia, Pisa, Italy; [3]NEST - Scuola Normale Superiore, Pisa, Italy; [4]Graphene Labs, Istituto Italiano di Tecnologia, Genova, Italy; [5]IFN-CNR, Milan, Italy

We use broadband transient reflection spectroscopy to investigate the ultrafast hot electron/hole transfer dynamics in graphene/WS2 heterostructures. The extracted timescale for this process is faster than 20 fs.

EI-4.3 WED 11:15

Cavity enhanced light-matter interaction in a graphene photodetector

•S. Schuler[1], D. Van Thourhout[2], A. Montanaro[3], S. Marconi[3], V. Sorianello[3], M. Romagnoli[3], S. Wachter[1], K. Watanabe[4], T. Taniguchi[4], and T. Mueller[1]; [1]Technical University of Vienna, Institute of Photonics, Vienna, Austria; [2]Ghent University-IMEC, Photonics Research Group, Gent, Belgium; [3]Consorzio Nazionale per le Telecomunicazioni, Photonic Networks and Technologies National Lab, Pisa, Italy; [4]National Institute for Materials Science, Tsukuba, Japan

The integration of graphene onto a ring resonator gives rise to a temperature of several hundred kelvin of the photo-excited carriers, resulting in a strong photoresponse due to the photo-thermoelectric effect.

ROOM 13a ICM

CA-9.3 WED 11:00

160-mJ Cryogenically-Cooled Yb:YLF Amplifier System at 1019 nm

•H. Cankaya[1,2,3], U. Demirbas[1,4], M. Pergament[1], M. Hemmer[1], Y. Hua[1,2], L.E. Zapata[1], and F.X. Kärtner[1,2,3]; [1]Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany; [2]Physics Department, University of Hamburg, Hamburg, Germany; [3]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany; [4]Laser Technology Laboratory, Antalya Bilim University, Antalya, Turkey

We demonstrate 160-mJ pulses from a cryogenically cooled Yb:YLF amplifier system at 10Hz. The spectrum supports sub-ps pulses around 1019nm. The amplifier consist of an Yb:fiber front-end, a regenerative amplifier and two four-pass amplifiers.

CA-9.4 WED 11:15

High average power, multiterawatt femtosecond laser chain enabling 10.19 W/cm2 at 100 Hz

•R. Clady, L. Charmasson, A. Ferre, O. Uteza, and M. Sentis; Aix-Marseille Université, CNRS, Marseille, France

We present the characterization of a high average power (>22W), high peak power (>9TW) laser chain. A control of the thermally induced distortions allows to reach peak intensities above 10.19W/cm2 on target at 100 Hz.

ROOM 13b ICM

CK-11.3 WED 11:00

Observation of elastic anisotropy in strained optical nanofibers using Brillouin spectroscopy

•A. Godet, J. Chrétien, T. Sylvestre, J.-C. Beugnot, and K. Phan Huy; Institut FEMTO-ST, Besançon, France

We investigate both theoretically and experimentally Brillouin light scattering in silica optical nanofibers under tensile strain and show that the fundamental elastic properties of silica dramatically change due to elastic anisotropy.

CK-11.4 WED 11:15

Tunnelling and free propagation of slow whispering gallery modes near the cutoff wavelength of an optical fibre

•Y. Yang and M. Sumetsky; Aston Institute of Photonics Techologies, Birmingham, United Kingdom

We present the first experimental demonstration of slow propagation and tunnelling of whispering gallery modes near the cutoff wavelength of an optical fibre. The results of measurements are in good agreement with the developed theory.

ROOM 14a ICM

EF-4.2 WED 11:15

Experimental Observation of Second Harmonic Generation Enabled by Longitudinal Components in Indium Gallium Phosphide Nanowires

•N. Poulvellarie[1,2], U. Dave[3], K. Alexander[2], C. Ciret[4], S.-P. Gorza[1], F. Raineri[5], S. Combrié[6], A. De Rossi[6], G. Roelkens[2], B. Kuyken[2], and F. Leo[1]; [1]OPERA-Photonics ,Université libre de Bruxelles, Brussels, Belgium; [2]Photonics Research Group, Department of Information Technology, Ghent University-IMEC, Ghent, Belgium; [3]Department of Electrical Engineering, Columbia University, New York, USA; [4]Laboratoire de Photonique d'Angers, Angers, France; [5]Laboratoire de Photonique et de Nanostructures, CNRS, Marcoussis, France; [6]Thales Research and Technology, Palaiseau, France

We demonstrate second harmonic generation in Indium Gallium Phosphide waveguides through the mixing of transverse and longitudinal components of the electric field. We confirm the excitation of an antisymmetric second harmonic mode through modal imaging.