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Mid-IR spectroscopy on a chip for label-free detection of bio-markers

Hans Schuessler, Alexandre Kolomenskii, James Bounds
Physics and Astronomy, Texas A&M University, College Station, TX, USA
Junchao Zhou, Paotai Lin
Electrical and Computer Engineering, Texas A&M University, College Station, USA
Genny Carrillo
Department of Environmental and Occupational Health at the Texas A&M School of Public Health

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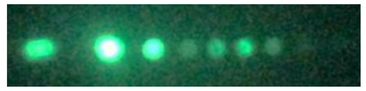
Miniaturization of optical sensors is an emerging technology that integrates nano optoelectronic components to realize "laboratory on a chip" to perform chemical or bio-analyses. This multidisciplinary research project investigates novel concepts of miniaturized sensors, which can provide a new analytical platform for diagnostics and personal care.

Coupling of light into a waveguide for a nonlinear conversion

coupling grating waveguide

different diffraction orders



$LiNbO_4$ on TiO_2 substrate

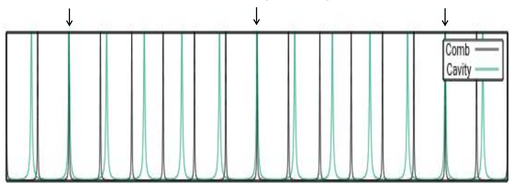
$$k_L \sin(\theta) + k_{gr} = \beta k_0 n$$

$$\lambda_L / \Lambda_{gr} + \sin\theta = \beta n, \quad \Lambda_{gr} \sim 4\mu m\,(N = 250 groves/mm)$$

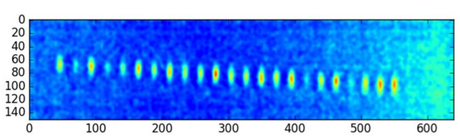
where $\beta = 1/\sqrt{1 - k_\perp^2 / k_w^2}$, $k_\perp = \pi / a$

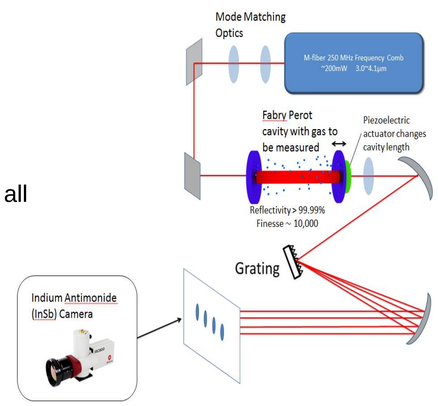
Frequency comb Vernier spectroscopy of methane in the mid-IR with temporal retrieval of comb lines

- Choosing the ratio of the cavity FSR to the comb repetition rate as (N+1)/N , we obtain simultaneous intracavity absorption enhancement as well as a tunable effective comb spacing



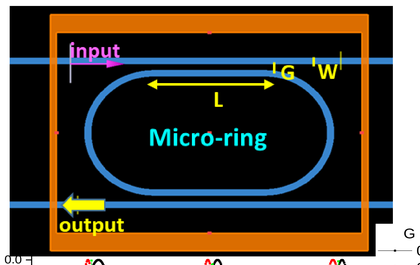
- In a table top experiement, we have shown that all comb lines can be retrieved by scanning the relative spacing around the Vernier ratio





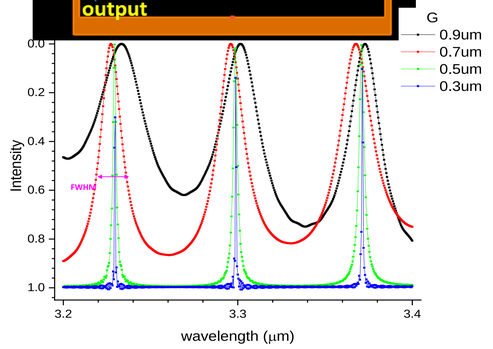
Jessica John, Juha Baek, Taehyun Roh, Lucia Cabrera-Conner, Genny Carrillo, "Regional Disparity in Asthma Prevalence and Distribution of Asthma Education Programs in Texas", *Journal of Environmental and Public Health*, vol. 2020, Article ID 9498124, 11 pages, 2020. https://doi.org/10.1155/2020/9498124
Schuessler, Hans A, Zhou, Junchao; Lin, Paotai; Kolomenskii, Alexander; Zhu, Feng; Bounds, James R. 73d International Symposium on Molecular Spectroscopy, Mini-symposium: Frequency-Comb Spectroscopy, Abstracts & Presentations, Illinois, 06/18, http://hdl.handle.net/2142/100480

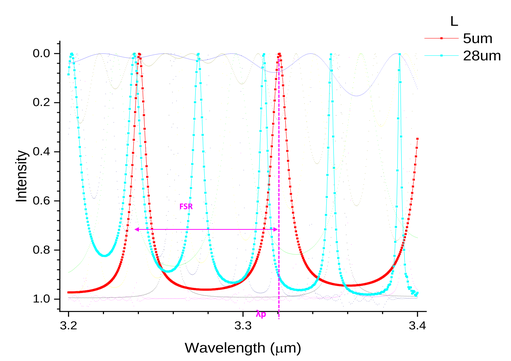
Design of the micro-resonators



Structure parameters
- **W:** Waveguide width
- **G:** Gap
- **L:** Racetrack length
- **n:** Refractive index

Spectrum Engineering
- **λp:** Resonance peak
- **FSR:** free spectrum range
- **FWHM:** Full width half maximum

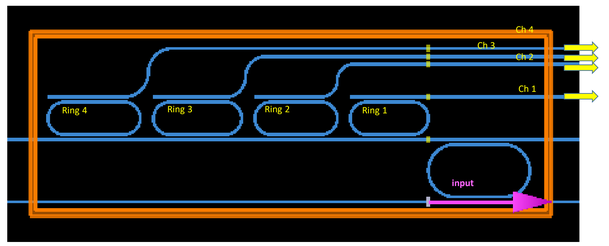




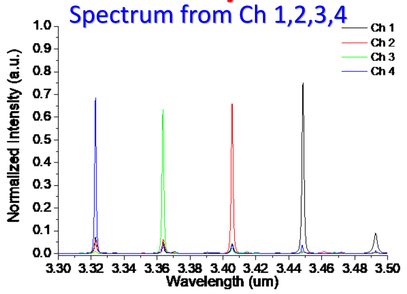
- The micro-resonator is the sorting element to edit the infrared spectrum.
- The spectrum selection is determined by the resonator structure.

Mid-IR cascade micro-resonator array

Cascade array

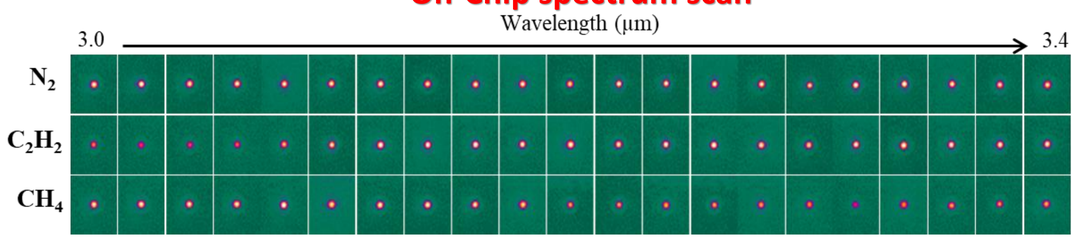


Spectrum from Ch 1,2,3,4

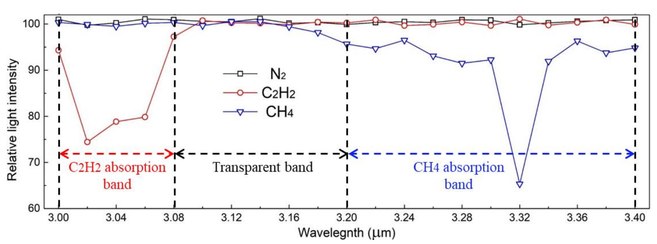


- The photonic chip comprised of cascade micro-resonators can create a multi-channel spectrometer with wavelengths precisely aligned with target molecular absorptions.

On-Chip spectrum scan



Waveguide mode vs. wavelength



- Different gases can be identified through infrared spectrum scanning using a photonic chip. Methane and acetylene show different absorption bands.

*T. Jin, J. Zhou, P. T. Lin, "Real-time and Non-destructive Hydrocarbon Gas Sensing Using Mid-Infrared Integrated Photonic Circuits," *RSC Adv.* 10, 7452-7459 2020
*J. Yang, P. T. Lin, "Real-time and Non-destructive Gas Mixture Analysis Using Linear Various Filter Enabled Mid infrared Visualization," *Opt. Express* doi.org/10.1364/OE.27.026512 2019
*T. Jin, H.-Y. G. Lin, T. Tiwald, P. T. Lin, "Flexible Mid-infrared Photonic Circuits for Real-time and Label-Free Hydroxyl Compound Detection," *Sci. Rep.* 9, 4153 2019