Multi-wavelength pseudoheterodyne interferometry for near-field imaging

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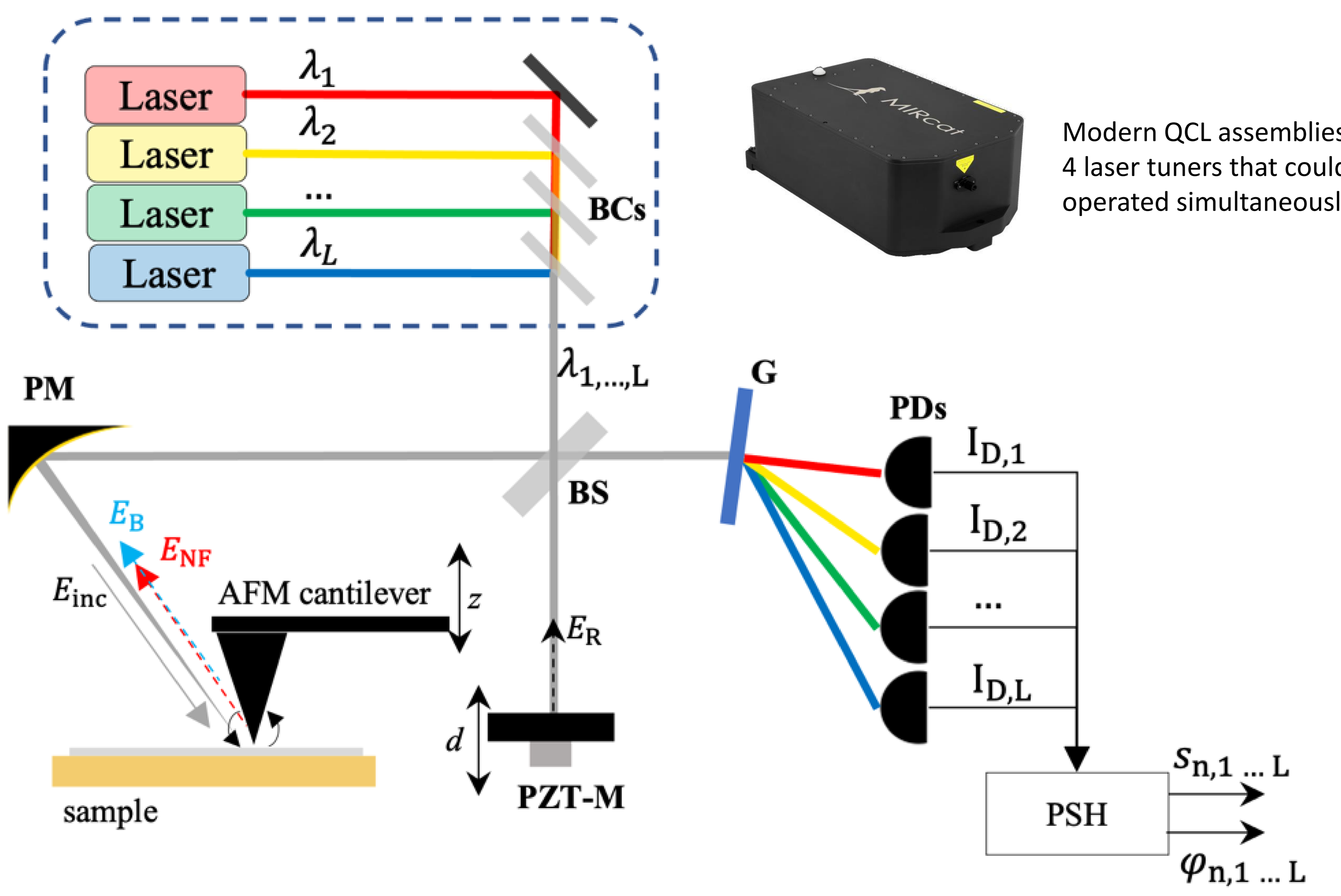
Abstract

We introduce multispectral pseudoheterodyne (PSH) interferometry, where infrared lasers are combined to form a beam with a discrete spectrum of laser lines and a time-multiplexing scheme is employed to allow for the use of a single infrared detector. We demonstrate its application for the real-time correction of the negative phase contrast (NPC), which provides reliable imaging of weak IR absorption on the nanoscale. We anticipate that multispectral PSH could improve data throughput, reduce effects of sample and interferometer drift and help to establish multicolor s-SNOM imaging as a regular imaging modality, which could be particularly interesting as new infrared light sources become available.

[1] Edoardo Vicentini et al., "Pseudoheterodyne interferometry for multicolor near-field imaging" (submitted)

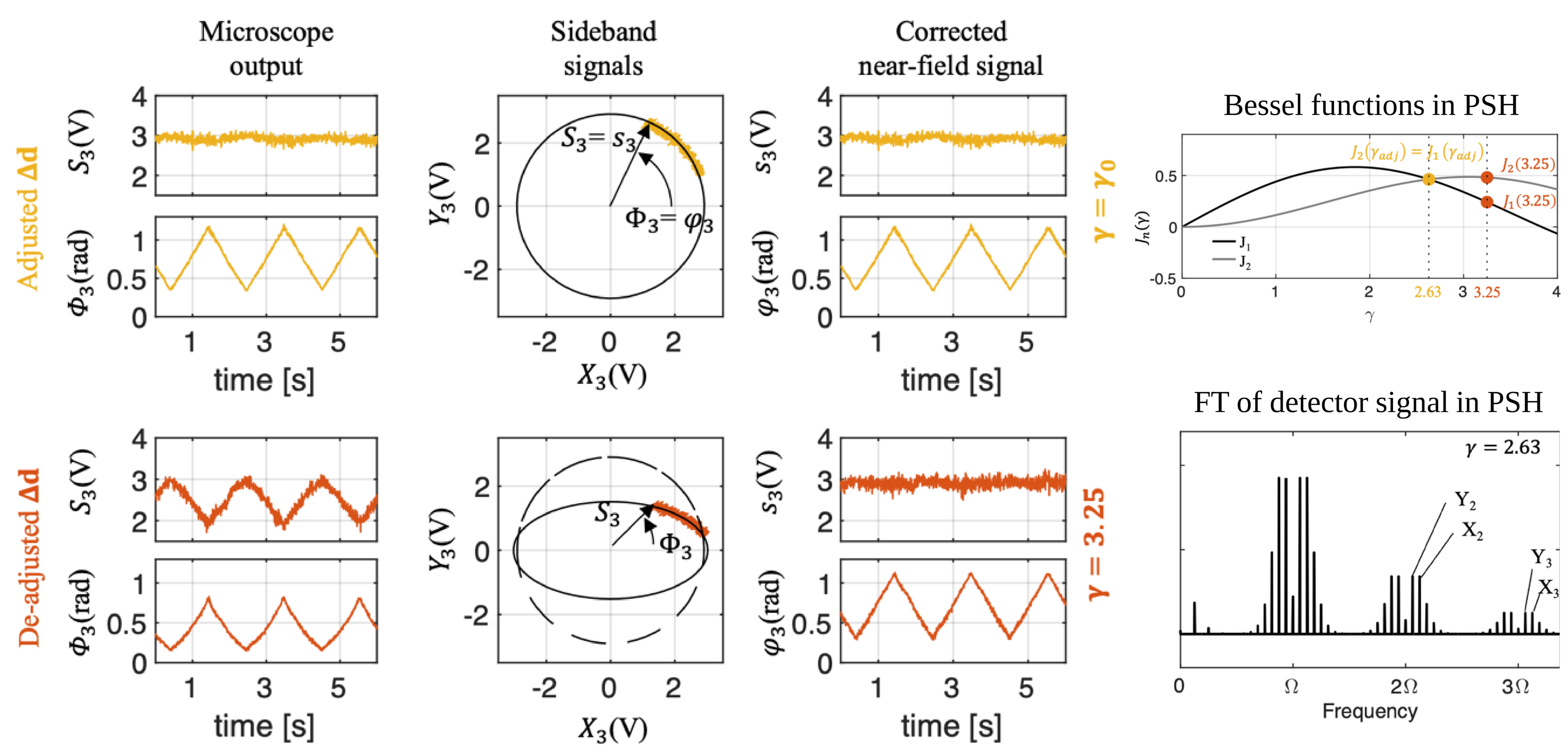
Multispectral PSH Concept



Modern QCL assemblies house 4 laser tuners that could be operated simultaneously

- Spectral imaging at multiple laser lines at high speed
- Wavelength-information is perfectly coregistered, enabling
  - Chemical composition mapping
  - Data processing with machine Learning
- Sources: Multi-tuner QCLs, possibly: broadband laser sources
- Spectra detector: Grating spectrometer & Detector array

Operation at arbitrary phase-modulation depths



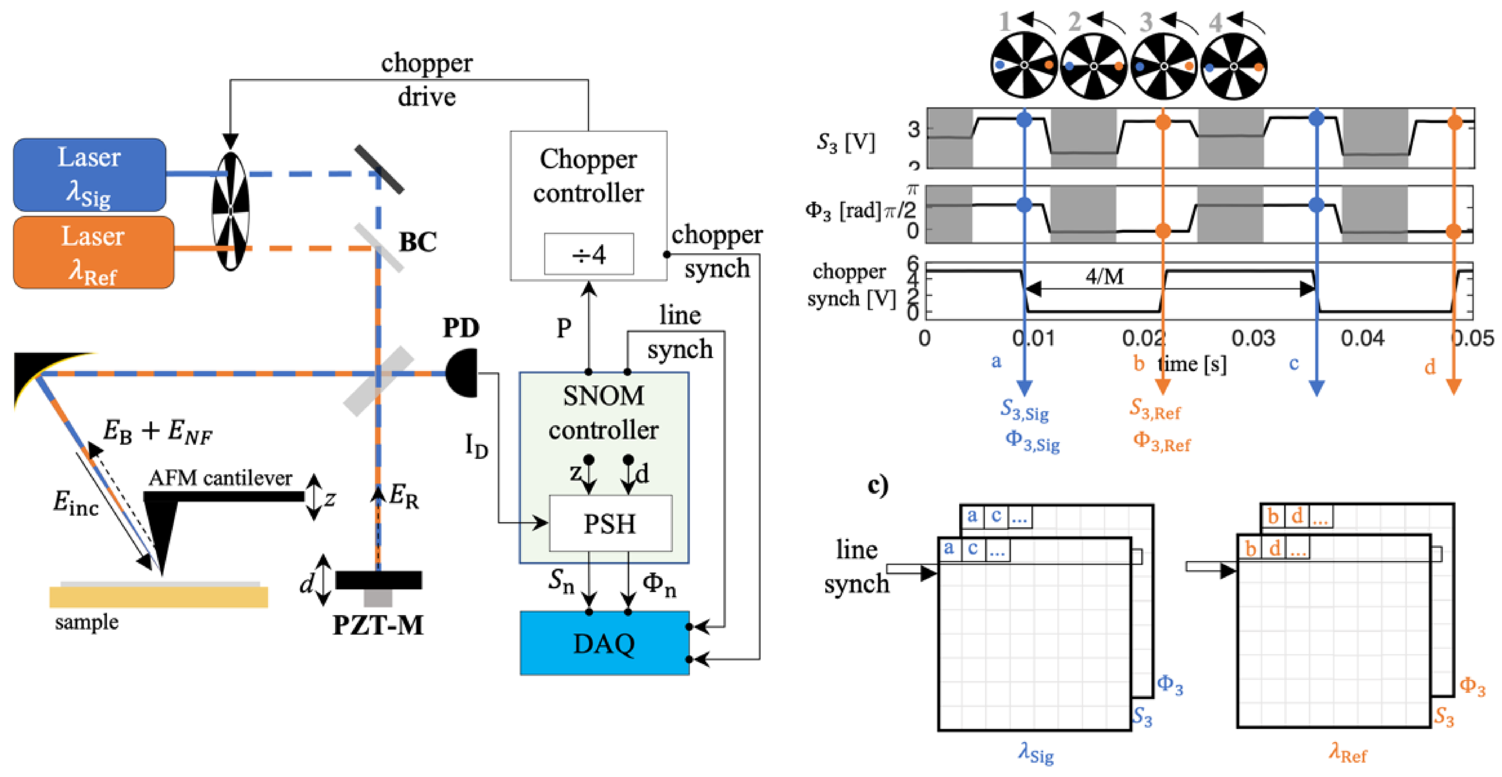
Near-field signals are obtained from sidebands by taking into account the value of the Bessel functions $J_{1,2}$

$$s_n e^{i\varphi_n} \propto \left(\frac{X_n}{J_2(\gamma)} + i\frac{Y_n}{J_1(\gamma)}\right),$$

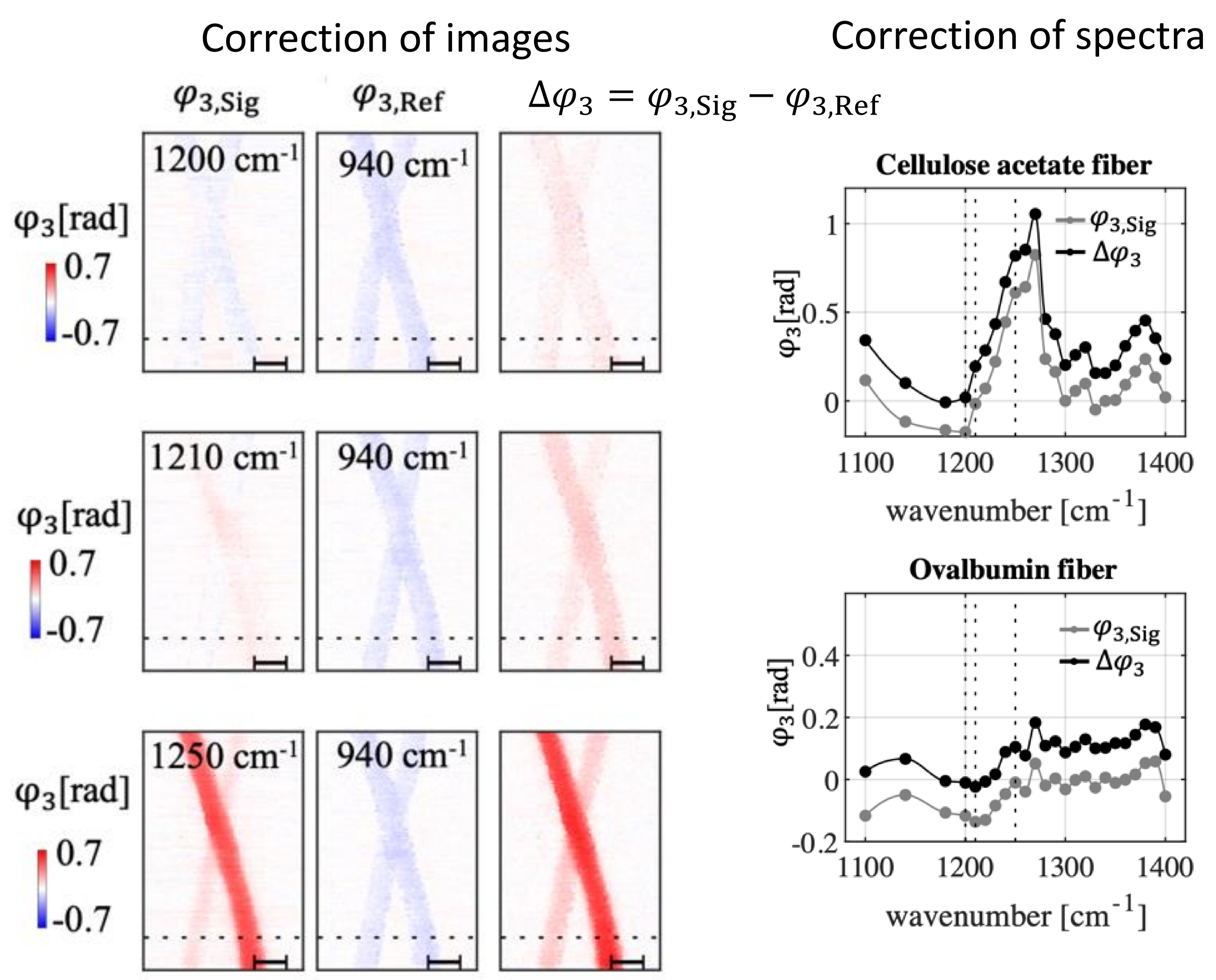
with phase-modulation depth, $\gamma = 4\pi \cdot \Delta d/\lambda$, is set by the laser wavelength, λ, and mirror vibration amplitude, Δd = cnst.

Multispectral PSH with time-division multiplexing

Current implementation of multispectral PSH using two lasers



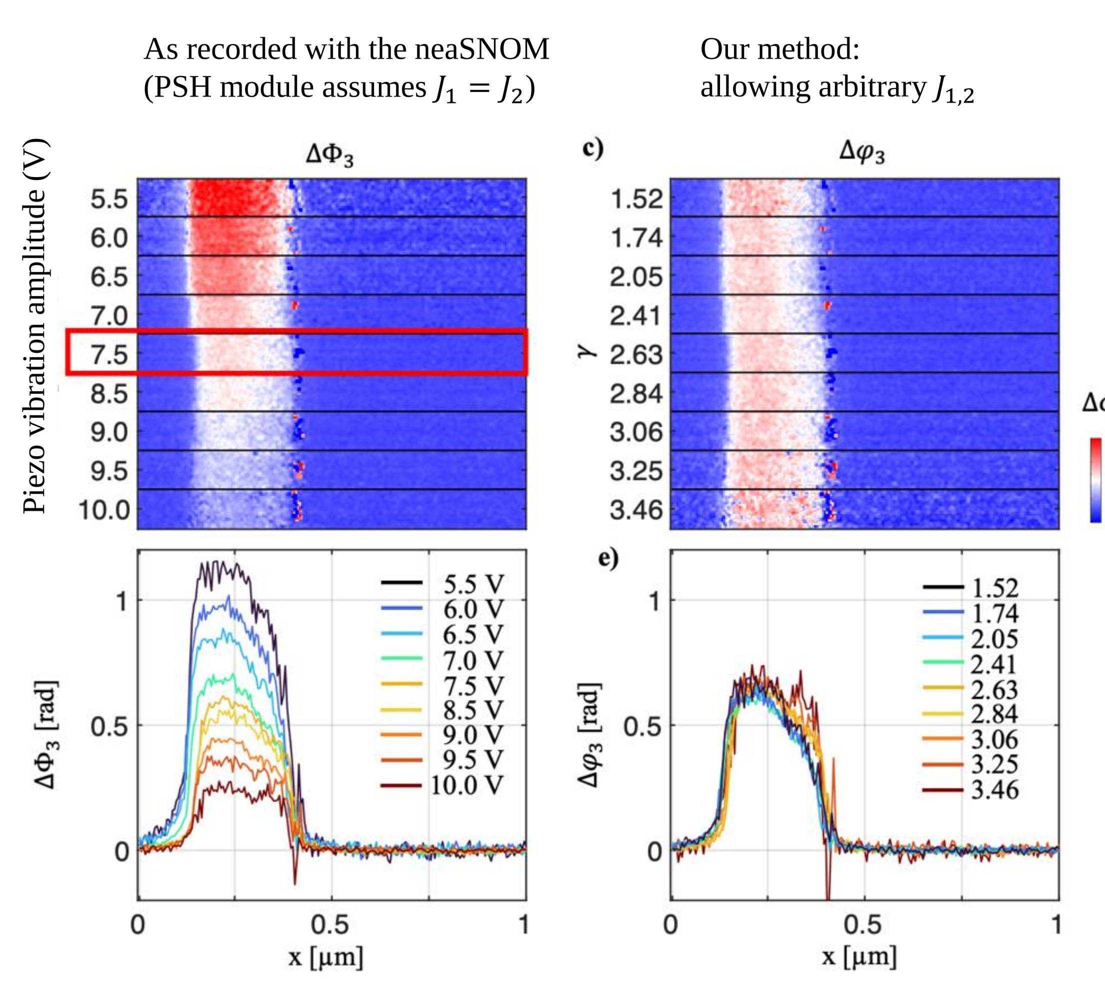
Real-time correction of the negative phase contrast



NPC: small refractive index sample placed on high refractive index substrate

Two-wavelength imaging:
We removed the NPC by referencing to the phase signal obtained at a known non-absorbing frequency.

Validation of NF phase contrast



Rescaling of the sidebands

$$s_{n,l}e^{i\varphi_{n,l}} = \mathrm{Re}\{S_{n,l}e^{i\Phi_{n,l}}\}\frac{J_2(\gamma_0)}{J_2(\gamma_l)} + i\,\mathrm{Im}\{S_{n,l}e^{i\Phi_{n,l}}\}\frac{J_1(\gamma_0)}{J_1(\gamma_l)}$$

We fixed laser wavelength, λ, and varied mirror vibrataion amplitude, Δd.

We obtain the same phase contrast on a test sample!

Acknowledgements

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