Self-Detection Near Field Optical Microscopy Based on Terahertz Quantum Cascade Laser

C Silvestri[1], L L Columbo[2], A D Rakic[1], and M Brambilla[3]

[1] *School of Information Technology and Electrical Engineering, University of Queensland, Brisbane, Australia*
[2] *Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, Turin, Italy*
[3] *Dipartimento Interateneo di Fisica, Politecnico di Bari, Bari, Italy*
Contact Email: c.silvestri@uq.edu.au

The self-detection scattering type near field optical microscopy (SD s-SNOM) is a detectorless technique with sub-wavelength resolution used for the retrieval of the dielectric properties of a resonant material sample in the terahertz (THz) range [1]. In this configuration (Fig. 1a) a Quantum Cascade Laser (QCL) acts as source and detector of THz radiation exploited first to interrogate the target sample by a near-field interaction mediated by an oscillating tip of an atomic force microscope and then, once back-reflected into the QCL, to induce laser terminals voltage variations that bring information about the sample optical response. In this work, we model the dynamics of the QCL in the SD s-SNOM scheme by using the Lang-Kobayashi equations [2], modified with the introduction of a complex scattering coefficient. In this theoretical framework, we derive an approximated procedure for the retrieval of the sample dielectric function (Fig. 1b) in the weak feedback regime (Acket parameter C<1), where the power of the self-mixing signal is higher than in the commonly used very weak feedback regime (C<0.1) [3], thus potentially improving the signal-to-noise ratio. Our method provides an accurate estimation of the phonon resonances for a supposed Cesium Bromide (CsBr) sample (Fig. 1c) [4].

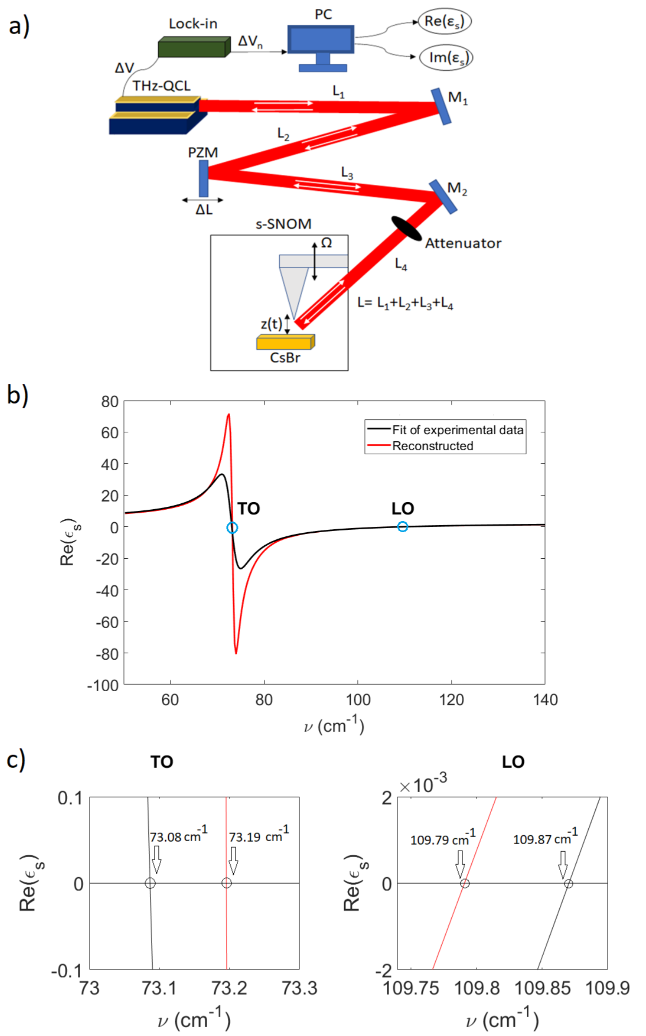

Figure 1: (a) SD s-SNOM setup. (b) Reconstructed (red) and fitted from experimental data (black) real part of the dielectric function of CsBr. (c) Zoom around the transverse optical (TO) and longitudinal optical (LO) phonon resonances

References

[1] M C Giordano, S Mastel, C Liewald, L L Columbo, M Brambilla, L Viti, A Politano, K Zhang, L Li, A G Davies, E H Linfield, R Hillenbrand, F Keilmann, G Scamarcio and M S Vitiello, Opt. Express **26**, 18423 (2018)

[2] R Lang and K Kobayashi, IEEE J. Quantum Electron. **16**, 347 (1980)

[3] E A A Pogna, C Silvestri, L L Columbo, M Brambilla, G Scamarcio and M S Vitiello, APL Photonics **6**, 061302 (2021)

[4] C Silvestri et al., IEEE J. Sel. Top. Quantum Electron. (2023), accepted