Minicolloque n° PMQ29 ☑ Oral ☐ Poster

Efficient generation of coherent acoustic phonons with fiber-integrated microcavities

M. Esmann[a,c*], O. Ortiz[a], F. Pastier[b], A. Rodriguez[a], Priya[a], A. Lemaître[a], C. Gomez-Carbonell[a], I. Sagnes[a], A. Harouri[a], P. Senellart[a], V. Giesz[b], and N. D. Lanzillotti-Kimura[a]

a. Université Paris-Saclay, CNRS, Centre de Nanosciences et de Nanotechnologies (C2N), Palaiseau
b. Quandela SAS, 10 Boulevard Thomas Gobert, 91120 Palaiseau, France
c. current affiliation: Department of Physics, Carl von Ossietzky Universität, 26129 Oldenburg, Germany

* email : m.esmann@uni-oldenburg.de

Coherent phonon generation by picosecond optical pump-probe spectroscopy [1] is an important experimental tool for studying acoustic properties at the nanoscale. In this work, we integrate semiconductor micropillar cavities confining near-infrared light and 18 GHz acoustic phonons with single-mode fibers. This approach solves three major challenges of existing pump-probe experiments using mechanical delay lines: (1) stability of the optical mode overlap, (2) reproducibility of the excitation conditions, and (3) high power densities limiting the range of compatible samples. These shortcomings have so far been a roadblock in establishing pump-probe spectroscopy as a quantitative tool for nanoacoustics.

Results

In this work, we simultaneously solve the three aforementioned challenges by integrating fibered systems into pump-probe experiments, lifting the necessity for any optical alignment during the experiments. We aligned and glued a single mode fiber onto an optophononic micropillar [3] beforehand as shown in Fig. 1.

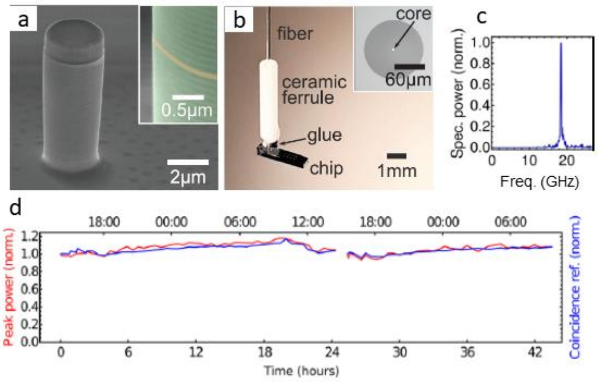

Figure 1 (a) Optophononic micropillar cavity. (b) Device integrated into a single mode fiber. (c) Nanophononic response of the device measured by pump-probe spectroscopy. (d) Stability of the response over 42h. Figure adapted from Ref. [2].

Our approach allows us to observe stable coherent phonon signals over at least a full day and at extremely low excitation powers down to 1µW. This excellent stability enabled us to perform detailed power dependence studies revealing complex dynamics of the optical and phononic modes [4]. Considering these dynamics, we are able to optimize excitation conditions and observe a mutual coherence between the optical and acoustic mode.
The monolithic sample structure is transportable and provides a means to perform reproducible plug-and-play experiments. The integration with fibers might also establish the missing link between high frequency acoustic phonon engineering and stimulated Brillouin scattering in structured optical fibers [5].

References

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