Activities of the Brillouin light scattering laboratory

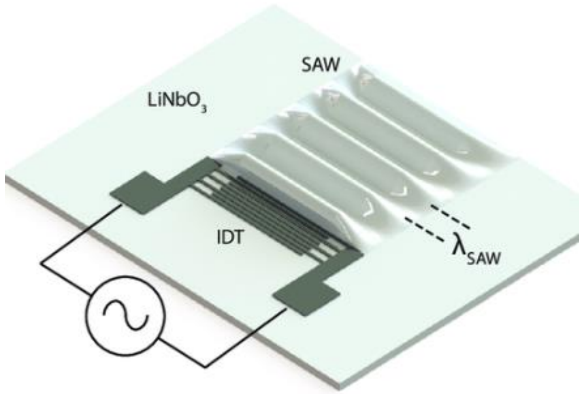
(department of Biophysics)

Members: Bartlomiej Graczykowski, Mikolaj Pochylski, Jacek Gapinski,

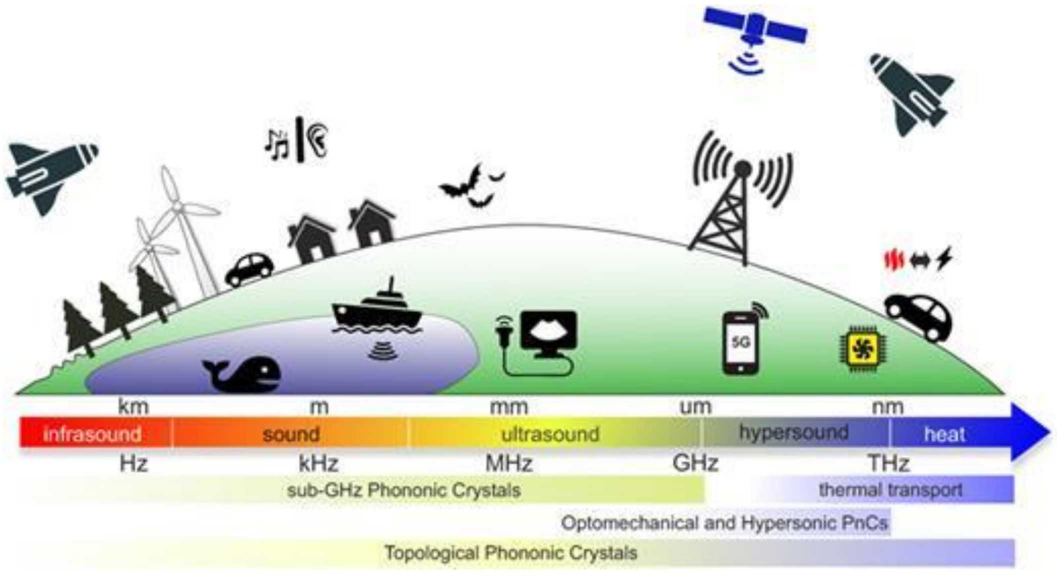
George Fytas, Thomas Vasileiadis, Adam Krysztofik, Rafal Bialek, Anuj Kumar Dhiman

Optomechanics & Phononics: Meaning & Motivation

1) Connecting different wavelengths

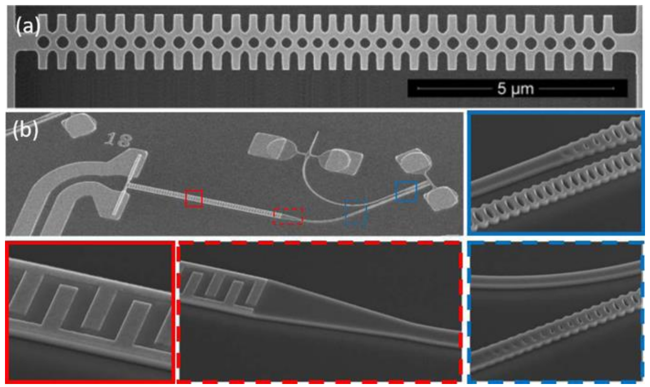


Armaghan Fakhfouri, PhD thesis, *Design of Surface Acoustic Waves Field for Manipulation of Particles in Microfluidics*. Monash University



J. Appl. Phys. 129, 160901 (2021)

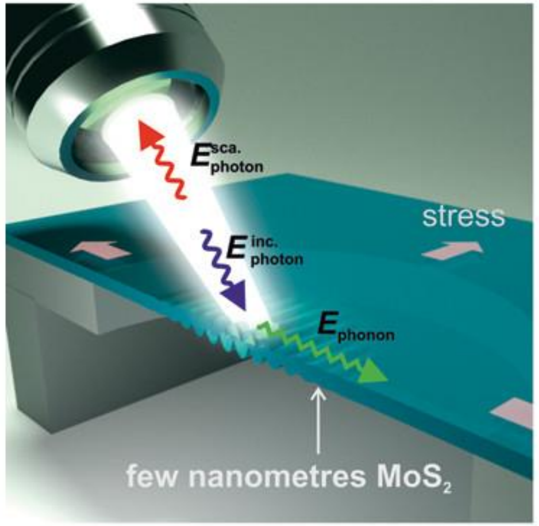
2) Connecting different frequencies

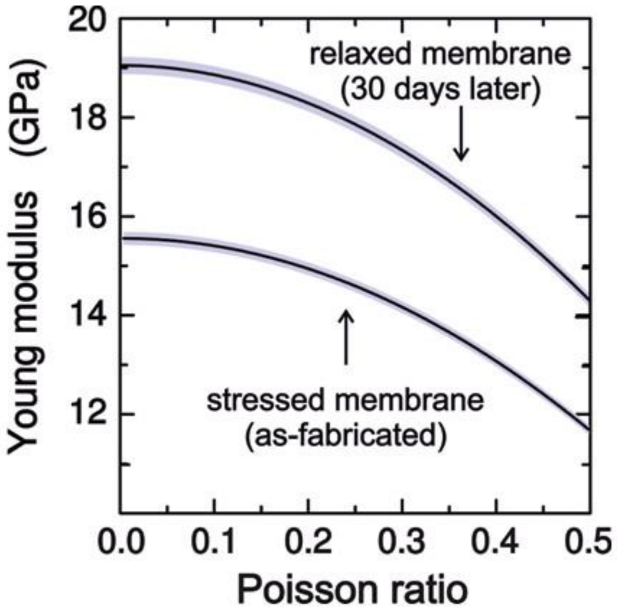


Sci. Rep. **5**, 1–7 (2015).
& Nat. Commun. 11, 1–7 (2020).

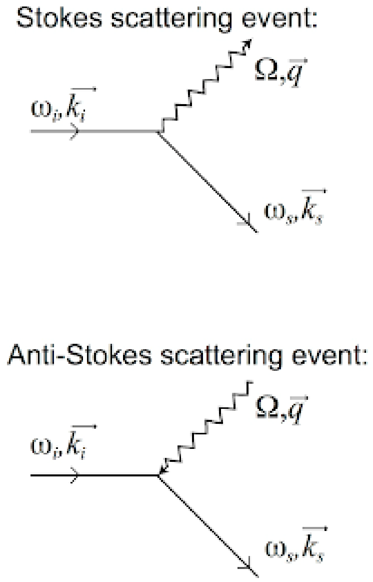
Brillouin light scattering (BLS):
A tool for studying mechanical and thermal properties

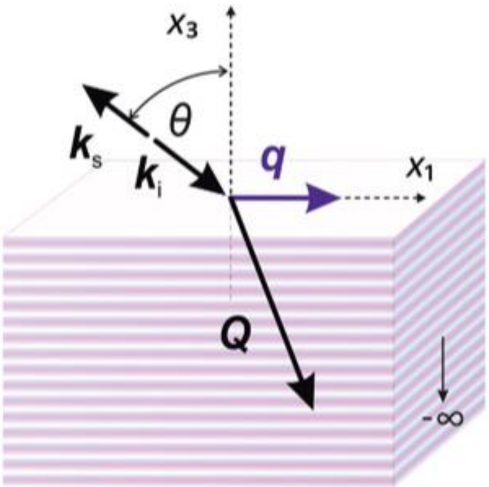
- Brillouin light scattering (BLS) is direct manifestation of optomechanical coupling.
- It can be used for contactless characterization of the mechanical and thermal properties of nanomaterials.





Graczykowski et al. Nano Lett. 2017, 17, 12, 7647–7651



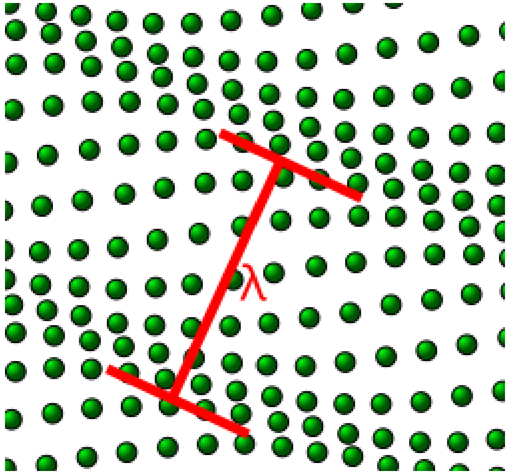


$$q = 4\pi \sin\theta / \lambda$$

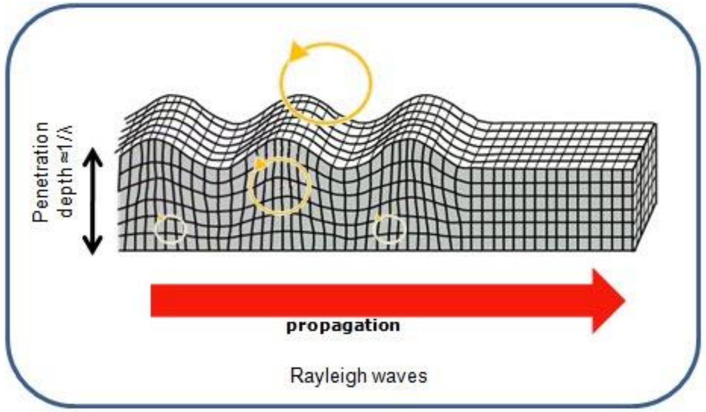
$$Q = 4\pi n/\lambda$$

BLS: From bulk transparent samples to nanomaterials

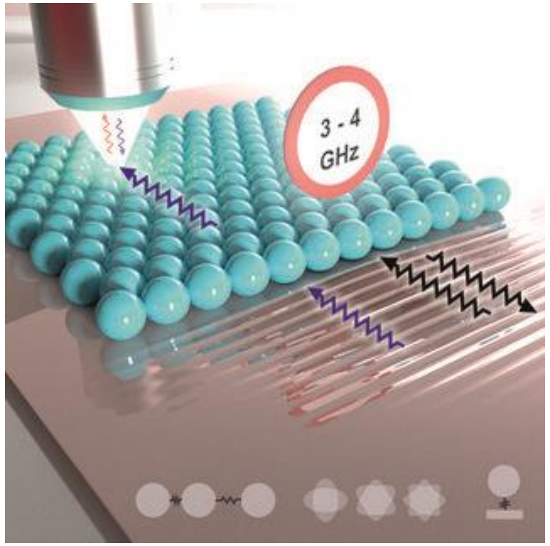
BLS studies started from bulk transparent glasses and liquids.....



Continued with surface acoustic waves (SAWs)



Now applied to nano- & meta-materials

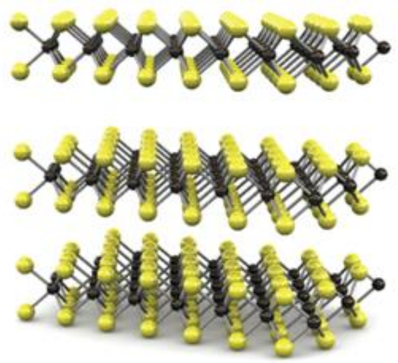


Graczykowski et al. Nano Letters , 20(3), pp. 1883–1889 (2020).

Types of projects:

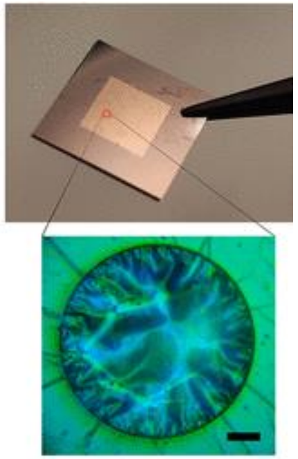
Low-dimensional
&
nanostructured materials

2D materials



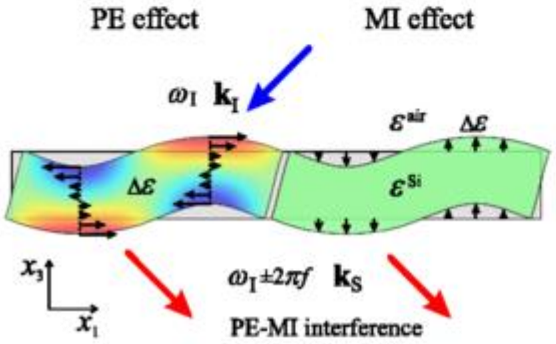
Babacic, Graczykowski, et al. Advanced Materials, 2021, 33(23), 2008614

Bio-inspired materials



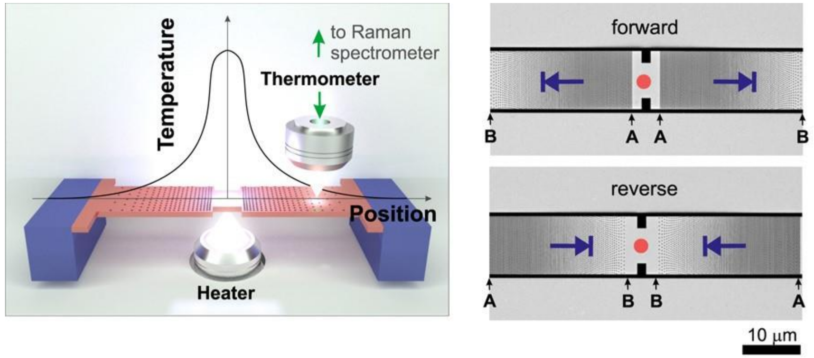
Nano Letters, 2022, 22(2), pp. 578–585

Semiconducting nanomembranes



Graczykowski et al. Physical Review B , 99(16), 165431

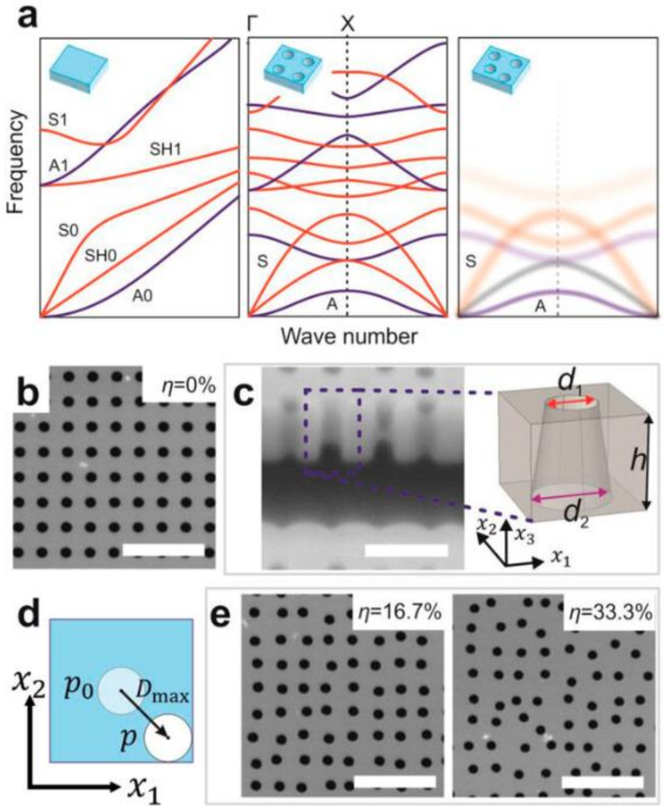
Metamaterials and novel devices



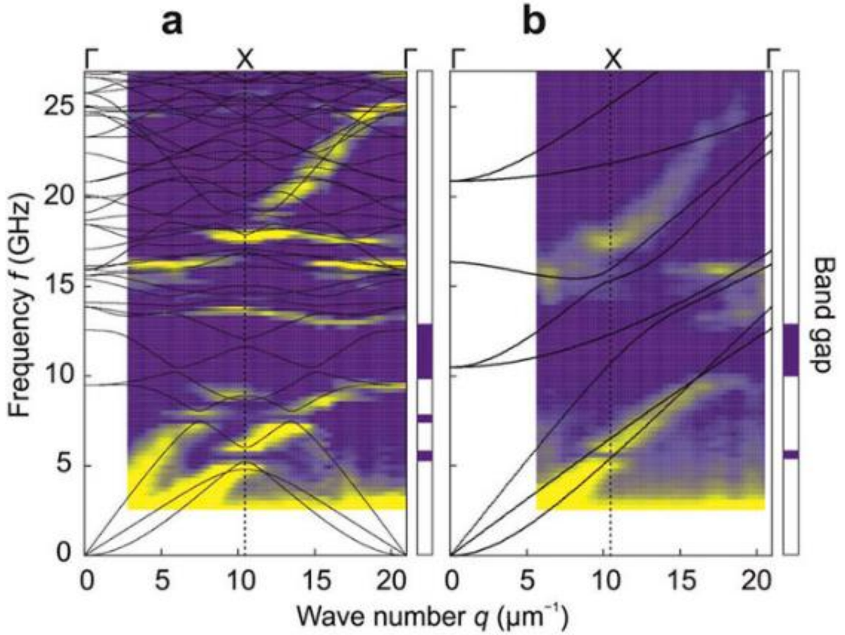
Graczykowski, Kasprzak, et al. High-temperature silicon thermal diode and switch, Nano Energy 78, 105261 (2020).

Recent examples: Phononic Crystals

A phononic crystal with varying degree of disorder



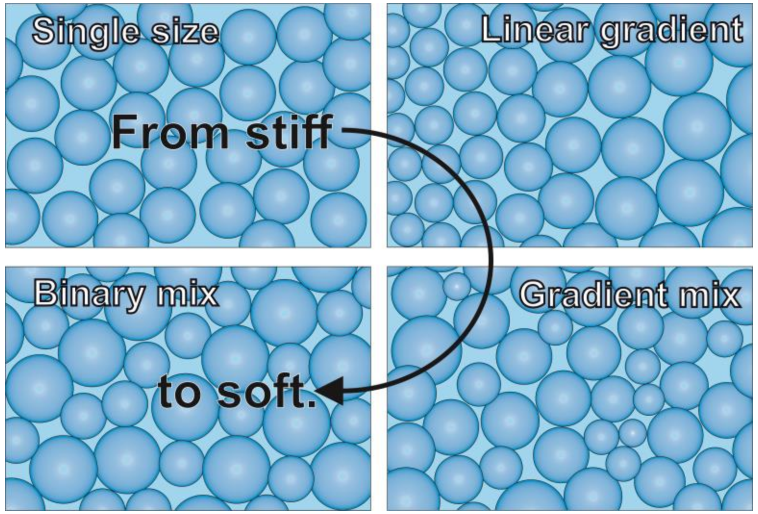
Excellent robustness to disorder

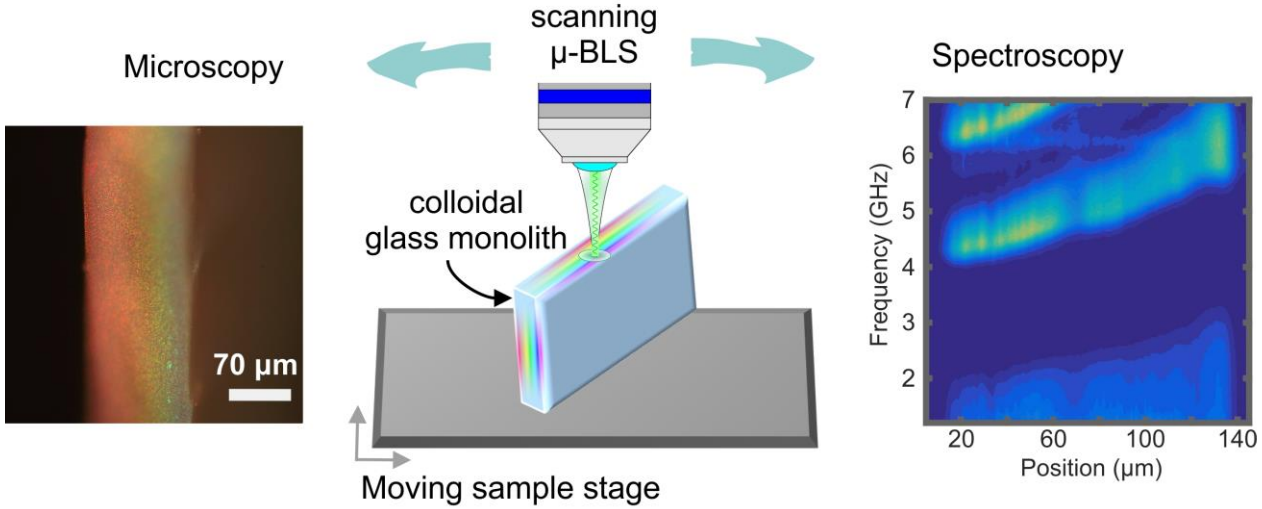


Babacic, Graczykowski, et al.
APL Materials, 2024, 12(4), 041108

Recent examples: Phononic Glasses

Elasticity Mapping of Colloidal Glasses Reveals the Interplay between Mesoscopic Order and Granular Mechanics





Collaboration with Markus Retsch,
Universität Bayreuth

Accepted in Small Methods, 2024

Pumped Brillouin Light Scattering (pump-BLS)

Pump-BLS: Novel method showing 330-fold enhancement of inelastic light scattering from a 260 nm-thick Si nanomembrane (compared with spontaneous BLS)

Science Advances 6, eabd4540 (2020).

SCIENCE ADVANCES | RESEARCH ARTICLE

PHYSICS

Frequency-domain study of nonthermal gigahertz phonons reveals Fano coupling to charge carriers

Thomas Vasileiadis[1,2], Heng Zhang[1], Hai Wang[1], Mischa Bonn[1], George Fytas[1]*, Bartlomiej Graczykowski[1,2]*

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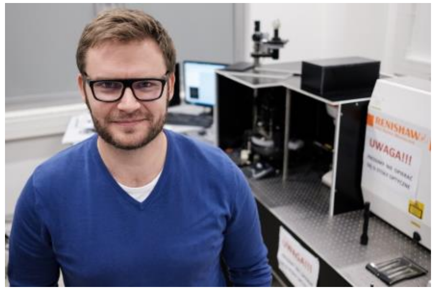
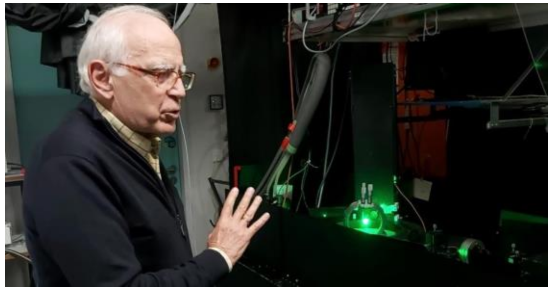
Telecommunication devices exploit hypersonic gigahertz acoustic phonons to mediate signal processing with microwave radiation, and charge carriers to operate various microelectronic components. Potential interactions of hypersound with charge carriers can be revealed through frequency- and momentum-resolved studies of acoustic phonons in photoexcited semiconductors. Here, we present an all-optical method for excitation and frequency-, momentum-, and space-resolved detection of gigahertz acoustic waves in a spatially confined model semiconductor. Lamb waves are excited in a bare silicon membrane using femtosecond optical pulses and detected with frequency-domain micro-Brillouin light spectroscopy. The population of photoexcited gigahertz phonons displays a hundredfold enhancement as compared with thermal equilibrium. The phonon spectra reveal Stokes–anti-Stokes asymmetry due to propagation, and strongly asymmetric Fano resonances due to coupling between the electron-hole plasma and the photoexcited phonons. This work lays the foundation for studying hypersonic signals in nonequilibrium conditions and, more generally, phonon-dependent phenomena in photoexcited nanostructures.

Bartlomiej Graczykowski



George Fytas

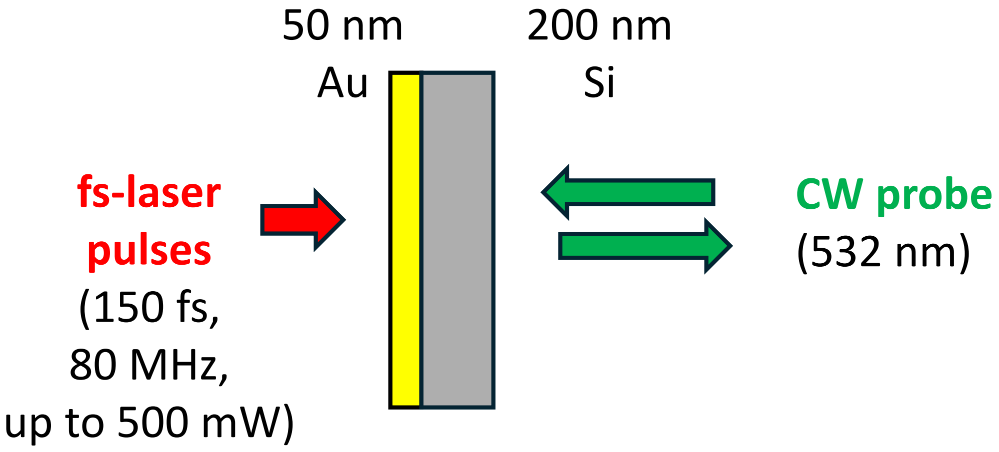


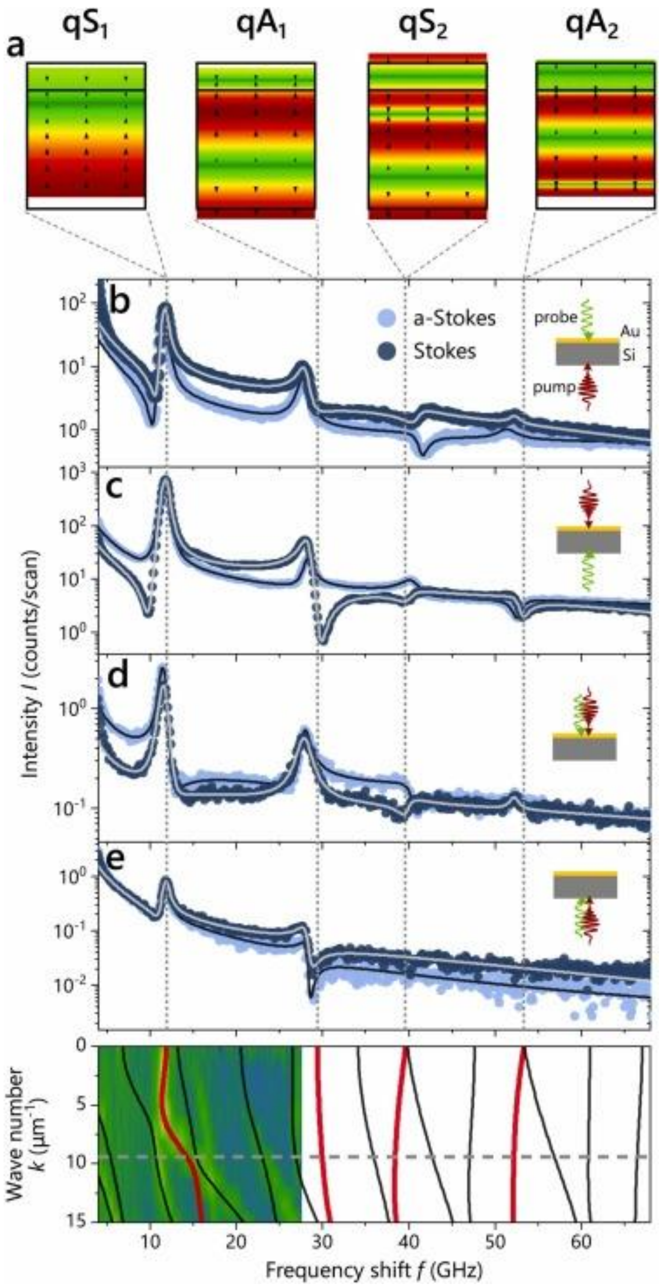
ADAM MICKIEWICZ UNIVERSITY POZNAŃ

MAX PLANCK INSTITUTE FOR POLYMER RESEARCH

Metal-semiconductor heterostructures

Rafał Białek, **Bartlomiej Graczykowski**, *et al.*
Photoacoustics Vol. 30, 100478 (2023)



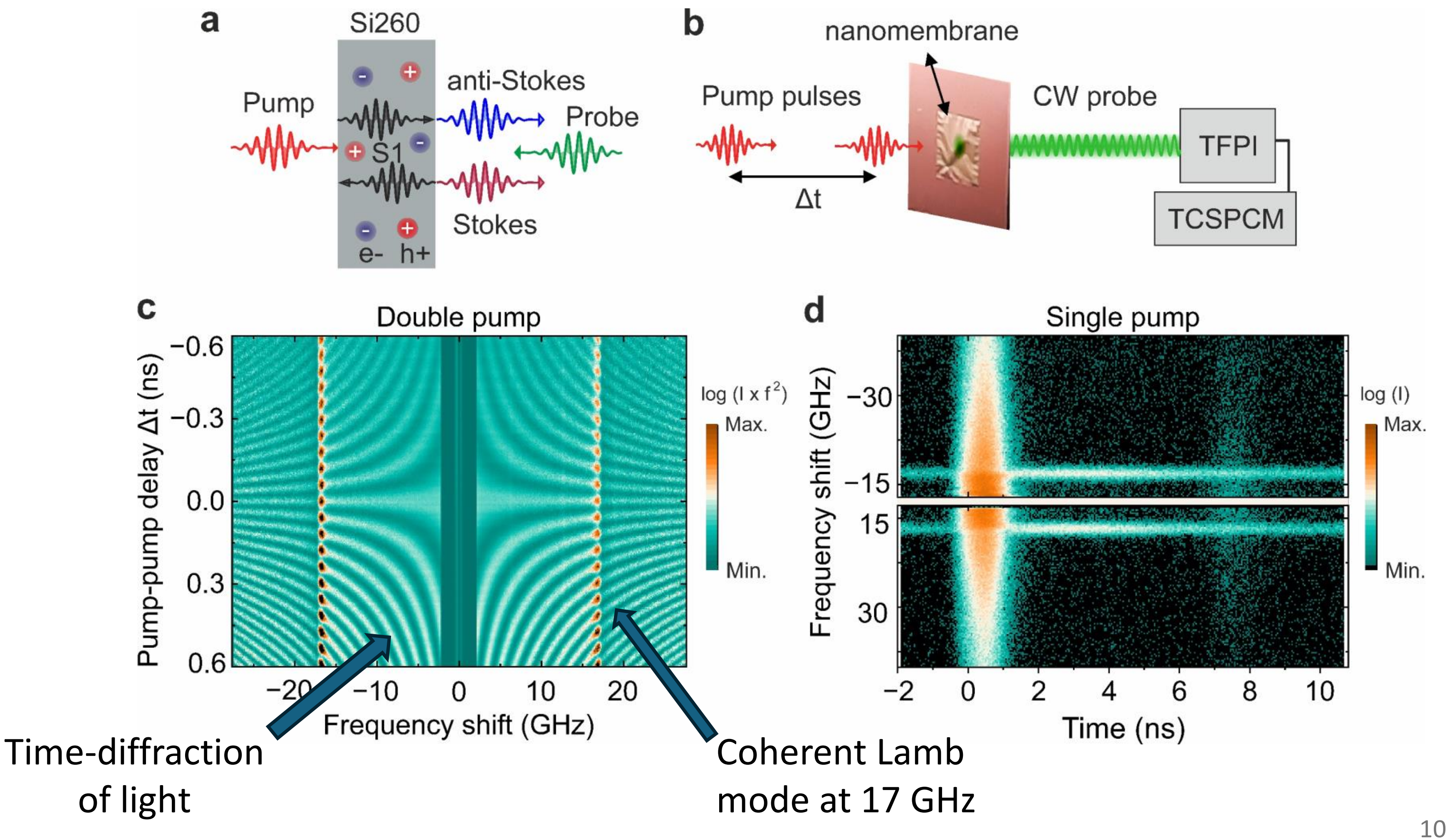


Inelastic light scattering on temporal interfaces

Pump-BLS with ***pairs*** of fs pump pulses

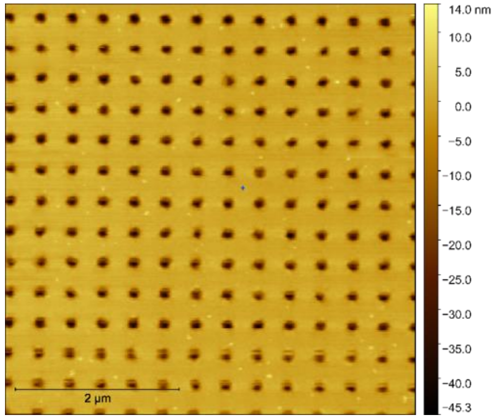
(wavelength 780 nm, pulse duration~150 fs) and a continuous wave probe (532 nm).

Work performed by Anuj Kumar Dhiman.

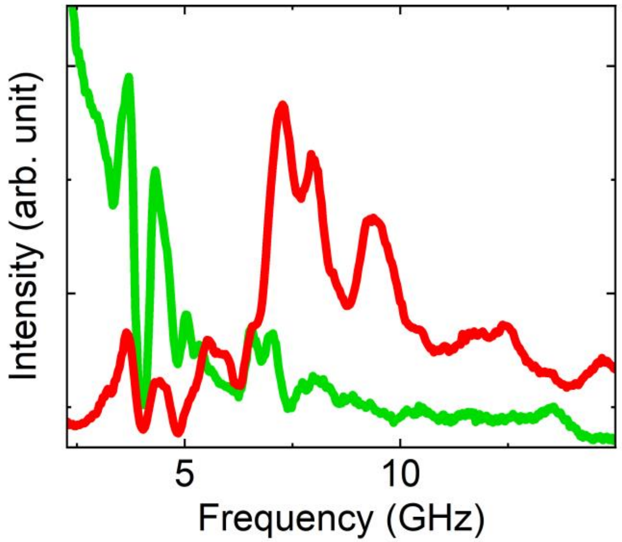


Acoustoplasmonics

Nanoholes
On Au/SiO2/Si
layers



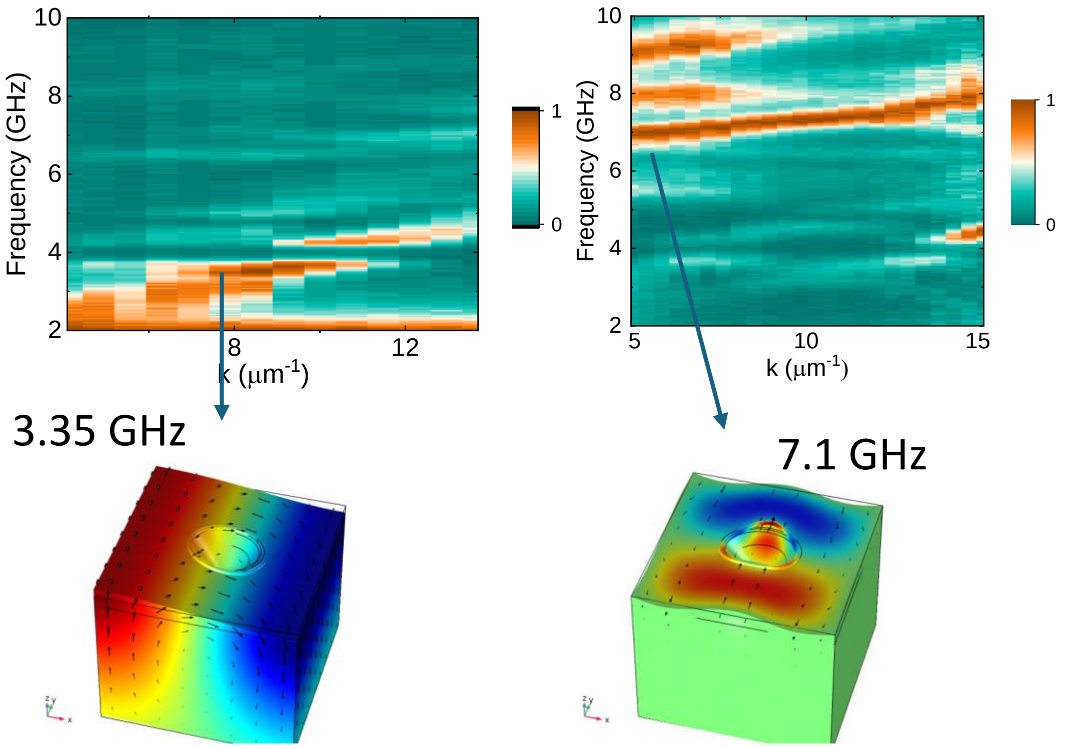
The obtained spectra depend
on the photon energy!



Mode-resolved mapping of
acoustoplasmonic coupling

λ=532 nm

λ=660 nm



Work performed by Hritika Dongre and Anuj Kumar Dhiman.