‘‘Time and momentum-resolved studies of gigahertz acoustic phonons in acoustoplasmonic metamaterials. (TM-RAM)’’ – **Thomas Vasileiadis.**

Fast signal-processing and transmission are essential for 5G networks, the Internet of Things, autonomous vehicles, telemedicine, and telecommuting, to name a few. Signal-processing devices transform gigahertz frequency (radiofrequency, RF) electromagnetic (EM) waves into acoustic waves/phonons with the aid of voltage pulses, metallic transducers, and piezoelectric crystals. These acoustic waves are approximately 10^5 slower than EM waves. Thanks to that, RF signals with few centimeters wavelengths can be converted to phonons of approximately micrometer wavelengths, which enables miniaturization of the signal processing devices for filtering and timing.

The ongoing increase of the wireless transfer rate and recent advances in terahertz research and integrated photonic networks demand the processing of signals at even higher frequencies. Higher frequencies of acoustic phonons can result from spatial confinement. Thus, as the operational frequency increases and the electronic devices get smaller it is highly expected that the conventional, bulk metallic transducers and piezoelectric crystals will transform into ultrathin metallic and semiconducting nanostructures, respectively.

Ultrasmall metallic nanostructures host charge oscillations called plasmons, while semiconducting nanomembranes host high-frequency acoustic phonons called Lamb acoustic waves. **The coupling of plasmons and Lamb waves can be exploited for next-generation signal-processing applications with the so-called acoustoplasmonic metamaterials.**

Acoustoplasmonic metamaterials operate far from thermodynamical equilibrium, meaning that their operation is based on well-defined (coherent) non-thermal acoustic phonons instead of plain, random, thermal motions. To observe the useful (but short-living) non-thermal Lamb waves in photoexcited acoustoplasmonics, we need measurements with a time resolution of at least one nanosecond. In addition, to fully comprehend the interactions of Lamb waves, we need to measure their wavelength and momentum. The relationships between frequencies and momenta, called band-structures, can then be used to understand the speed, symmetry, and interactions of the Lamb waves. The Lamb waves can modulate the frequency and momentum (direction) of a continuous laser beam. The tiny frequency shifts, termed Brillouin light scattering (BLS), can be detected with interferometric spectrometers. **The project aims to study transient band-structures and non-thermal populations of Lamb waves in membrane-like acoustoplasmonics, using time- and momentum-resolved Brillouin light scattering measurements.**

To achieve this goal, we will employ (1) numerical studies to design membrane-like, metallic-semiconducting acoustoplasmonic metamaterials, (2) nanofabrication based on electron beam lithography, (3) momentum-resolved BLS measurements of Lamb waves, (4) photoexcitation with ultrashort laser pulses and time-resolved BLS measurements using the laser pulses as a clock, and (5) theoretical and computational studies of plasmons, Lamb waves, and plasmon – Lamb wave coupling.

The expected substantial results of this project are (1) design and construction of crystalline arrays of plasmonic nanostructures on semiconducting nanomembranes for high-frequency signal-processing (>>10 GHz), (2) demonstration of plasmon-enhanced Brillouin light scattering, (3) observation of non-thermal Lamb wave generation at specific locations of their band-structure due to plasmons, (4) observation of Lamb waves’ decay and thermalization. **With these results, we will learn how to enhance the efficiency of acoustoplasmonics, by maximizing the useful energy transfer from plasmons to Lamb waves and by minimizing or delaying the generation of waste heat.**