Terahertz metasurfaces for detection of viruses and other biological substances

The project aims in realization of complete detection system of biomatter. Our goal is to study a possibility of trace detection of bio-particles like for example viruses and proteins with metasurfaces using terahertz radiation.

Why?

Coronavirus disease 2019 (**COVID-19**) is a newly emerging human infectious disease caused by severe acute respiratory syndrome coronavirus (SARS-CoV-2). Because no specific drugs or vaccines for COVID-19 are yet available, early diagnosis and management are crucial for containing the outbreak. That is why it is important to undertake study of the proposed project as it aims in virus sensing. Metasurfaces operating in the terahertz (THz) regime are an emerging alternative in this regard, as they have already shown a great potential in high-speed and on-site detection of microorganisms. Maybe the current outbreak of infections will not be contained using our biosensor, but basic research done in the project will for sure be helpful in the case of next pandemic, caused by some other virus or bacteria. Instant virus breathanalyzer could have enormous implications for air travel, with borders able to be re-opened and passengers mandatorily tested before flying.

Why terahertz radiation?

Detection of biomatter like viruses, proteins, etc. is of great importance for life sciences, mainly biology, biomedicine, and pharmaceutics. The terahertz band has very attractive characteristics for sensing and biosensing applications, due to some interesting features such as being a nonionizing radiation and very sensitive to weak interactions. Being situated between infrared light and microwave radiation, the **absorption of THz ray** in molecular and biomolecular systems is dominated by the excitation of investigated objects, which **is significant for molecule and biomolecule detections.**

What?

A **metamaterial** (meaning "beyond matter") is any material engineered to have a property that is not found in naturally occurring materials. Metamaterials derive their properties not from the properties of the base materials, but from their newly designed structures. Their precise shape, geometry, size, orientation and arrangement gives them their smart properties capable of manipulating electromagnetic waves: by blocking, absorbing, enhancing, or bending waves, to achieve benefits that go beyond what is possible with conventional materials.

Metasurface is a 2D metamaterial (thin two-dimensional metamaterial layer) which is a periodic array of scattering elements whose dimensions and periods are small compared with the operating wavelength. The main advantages of metasurfaces with respect to the existing conventional technology include their low cost, low level of absorption in comparison with bulky metamaterials, and easy integration due to their thin profile. In addition to exciting realizations mentioned above, metasurfaces are emerging as true game changers in the quest for designing ultrasensitive sensors all along the electromagnetic spectrum but with special relevance at THz frequencies. The key idea behind this type of sensors is to engineer (usually metallic) patterns with small details (slots or patches) to produce a strong field concentration at localized spots under an external source illumination. This intense field confinement enhances light-matter interaction with the substance under test, giving rise to a strong change in the spectral response.

Metasurface biosensors have been crucial in alleviating one of the biggest problems in THz biological sensing, which is the stark difference between the typical size of microorganisms (≈1 μm) and the wavelength at THz (≈30 to 1000 μm) that makes this radiation insensitive to these small details. Metasurface biosensors hold the promise to overcome these limitations taking advantage of the unprecedented freedom to engineer the metasurface parts properly. **THz metasurface sensing is not only signal-enhancing but also easy to operate**, which attracts significant attentions from researchers in diverse fields.

As we mentioned in the **introduction label-free THz sensing of trace amount of targets including biomolecules** is promising because of their rich spectral fingerprint in this electromagnetic region; however, improving the sensitivity remains to be a challenge, partially due to the limitations of THz sources and detectors. In the project we plan to address the problem of limitations of THz sources and detectors, by **constructing our own THz source and detector pair**, basing on plasma wave THz field effect transistors detectors and emitters.