Infrared metrology using visible light

Infrared (IR) spectroscopy and imaging are important techniques in material analysis, sensing and characterization. Although conventional methods of IR measurements are well developed, there are remaining challenges related to high cost and low efficiency of IR light sources and detectors. These challenges can be addressed using tools and techniques of nonlinear and quantum optics, which allow circumventing the need for IR-range components.

In this thesis, I describe a technique of IR measurements, which requires using only accessible light sources and detectors operating in the visible range. The method is based on the nonlinear interference of correlated photons produced via spontaneous parametric down conversion (SPDC) [1, 2]. In SPDC, a photon from the pump laser decays in a nonlinear crystal into a pair of highly correlated photons [3]. One photon of the pair can be generated in the visible range, and another in the IR range. Two identical nonlinear crystals pumped by the same laser form the nonlinear interferometer, where interference of the visible SPDC photons can be observed. The interference fringes for the visible photons depend on amplitudes and phases of the IR photons, which are used to probe properties of the medium under study. Hence the nonlinear interferometer allows study properties of the media in the *IR range*, when the actual measurements are performed in the *visible range*.

We applied the nonlinear interference technique for the development of IR spectroscopy, IR optical coherence tomography (OCT) and IR imaging. In IR spectroscopy experiment we measured refractive index and absorption coefficient of various samples in IR range, while detecting photons in the visible range. We demonstrated the application of the technique for studies of glass, organic polymer, Silicon and CO_2 gas. In IR OCT and imaging schemes, we measured of the reflectivity of internal interfaces of the sample, realized raster imaging through opaque layers and measured sample birefringence.

Our method shows a good precision in measurement of the absorption coefficient and refractive index of the media and in determining the position of reflecting layers of the sample in a broad range of IR wavelengths. The method does not require the use of expensive and inefficient IR detectors and sources, and it can be applied to a broad variety of samples. This work paves the way for further practical adoption of the method in the field of IR metrology, without resorting to IR grade detectors and sources.

References:

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[3] D. N. Klyshko, "Photons and Nonlinear Optics", *CRC Press*, (1988)