University of Fribourg / Faculty of Science and Medicine / Department of Physics

Design, Fabrication and Characterization of Ordered and Disordered Photonic Materials

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In this thesis, we describe the interaction of light with ordered and disordered photonic structures. Photonic materials influence light in peculiar ways. Often the center of interest are materials with a photonic band gap. This latter describes a range of frequencies where light is prohibited to enter the medium. For periodic dielectric structures, or photonic crystals, the emergence of the photonic band gap is well understood as the interference of electromagnetic radiation reflected at the Bragg planes. This reasoning is not applicable for amorphous photonic materials due to the lack of long-range order, a fully satisfying explanation is still missing. Furthermore, the influence of defects, which inevitably occur during production, on the scattering strength of the material is not well understood yet.

In the first part of the thesis, we design a writing protocol to fabricate two-dimensional photonic structures and we measure their transmittance. The structures are produced using direct laser writing (DLW). DLW uses a two-photon absorption process to polymerize a resist at the focal point of the laser. The comparison of the calculations and measurements show that we are able to create high quality 2D photonic structures with the predicted photonic features.

The second part is about reaching bandgaps with smaller wavelengths by heat-shrinking polymer photonic hyperuniform structures. Due to physical limitations, the minimum feature size reachable with the DLW set-up is limited. For some applications, smaller structures are required. We reduce the structure size by isotropically shrinking hyperuniform three-dimensional structures. By inverting them into a higher index material using atomic layer deposition and chemical vapor deposition, a band gap appears at wavelengths lower than 2µm.

The last part presents a study where we introduce defects in a woodpile photonic crystal to monitor its effects on the scattering properties. By adjusting the laser power in some segments of the woodpile structure we can generate thicker (positive defects) and thinner (negative defects) rod segments. We measure the reflectance and transmittance to calculate the scattering mean free path. The results show that for a low defect density, the defects act like a dilute gas of scatterers that can be described using the Rayleigh-Gans-Debye approximation.

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