Abstract

This doctoral dissertation consists of a series of four scientific articles that focus on the use of optical fibers as a measurement platform for investigating the properties of van der Waals crystals. The individual studies cover both the development and implementation of new spectroscopic techniques as well as their application to the analysis of optical phenomena in transition metal dichalcogenides (TMDCs).

The first article describes research on a photoreflectance and contactless electroreflectance setup enhanced with optical fibers, which allowed the physical separation of the measurement zone from the excitation source and detectors. Systematic studies of the fiber core diameter and sample-to-fiber distance revealed their impact on signal quality. This configuration in contactless electroreflectance measurements eliminated the shadow effect, increased measurement safety and amplified the signal.

Subsequent works expanded the concept of lab-on-fiber spectroscopy by transferring thin TMDC layers directly onto the fiber facet. This enabled the development of a thermotransmittance method, where local laser-induced heating led to measurable shifts in excitonic resonances and changes in the absorption coefficient, as described in the second article.

The third article presents further development of the system, which was extended to cryogenic measurements through the integration of a fiber-to-fiber adapter with a closed-cycle helium cryostat. This design provided exceptional stability, vibration resistance, and eliminated temperature drift, allowing the study of photoluminescence, transmission, photomodulated transmission, and photoreflectance over a wide temperature range. The system was successfully applied to thin films, monolayers, and heterostructures. An important aspect was the relatively low cost of constructing such a setup, thanks to the use of a commercially available closed-cycle cryostat.

In the final article, optical transmission spectroscopy of monolayer alloys based on MoS_2 is presented. The experiments showed that substituting sulfur with selenium leads to a redshift of excitonic transitions, while replacing molybdenum with tungsten results in a blueshift. It was also found that the temperature sensitivity of excitons strongly depends on alloy composition: tungsten- and selenium-rich structures exhibit larger energy shifts with temperature.

The results obtained in this dissertation indicate that fiber-optic techniques can expand the experimental capabilities for characterizing 2D materials. The developed fiber-based methods allow precise, stable, and versatile optical measurements under both ambient and cryogenic conditions and highlight the potential of this approach for future applications in spectroscopy and fiber-integrated devices based on van der Waals crystals.