# Optical spectroscopy of semiconductor microcavities (OS)

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## 1. Course objective

The aim of the experiment is to learn and understand the fundamentals of the interaction between electromagnetic waves and matter excitations and thus the physics of polaritons. Basic properties of exciton polaritons generated by optical pumping in a semiconductor microcavity will be investigated and analyzed.

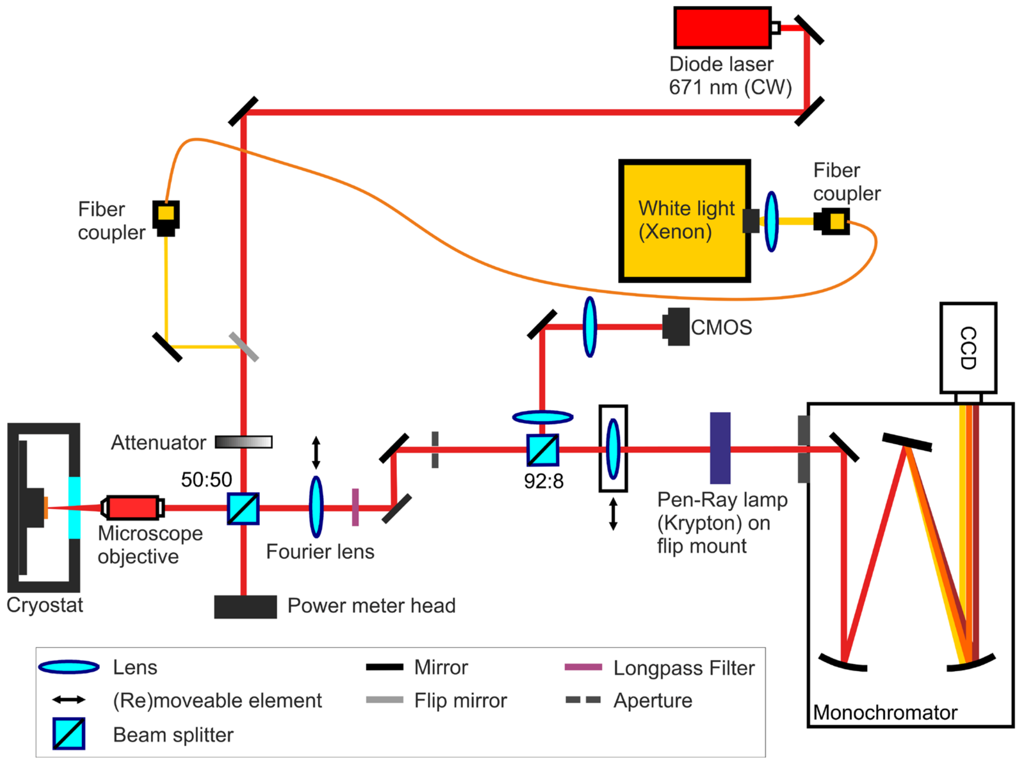


*Figure 1: Schematic of the experimental setup.*

## 2. Experimental Setup

The experimental setup is equipped with a diode laser, which emits in continuous wave (CW) mode at a fixed wavelength of 671 nm with an adjustable laser output power (up to a maximum of 400 mW). Due to the high output power, protective goggles must be worn during the entire lab course (available at the setup)! A broadband white light source (Xenon) is also available. The directed emission from the excitation laser and spectral lamp is deflected by mirrors onto a 50:50 cube beam splitter cube. The part of the light transmitted straight through the cube can be used for measuring the laser power, whereas the deflected part of the light is focused on the semiconductor microcavity through a microscope objective (50x, NA 0.42). The microcavity is located in a cryostat whose temperature can be lowered to 4K by liquid helium flow. The light emitted or reflected from the microcavity will be collected by the very same microscope objective, pass straight through the beam splitter cube, and be imaged onto the entrance slit of a monochromator. At the back output port of the monochromator is a Peltier-cooled CCD camera with a two-dimensional chip to detect the sample emission. Between the microscope objective and the monochromator there is also a 4f setup of lenses to image both the real and the Fourier image of the sample on the detector (see figure 2).

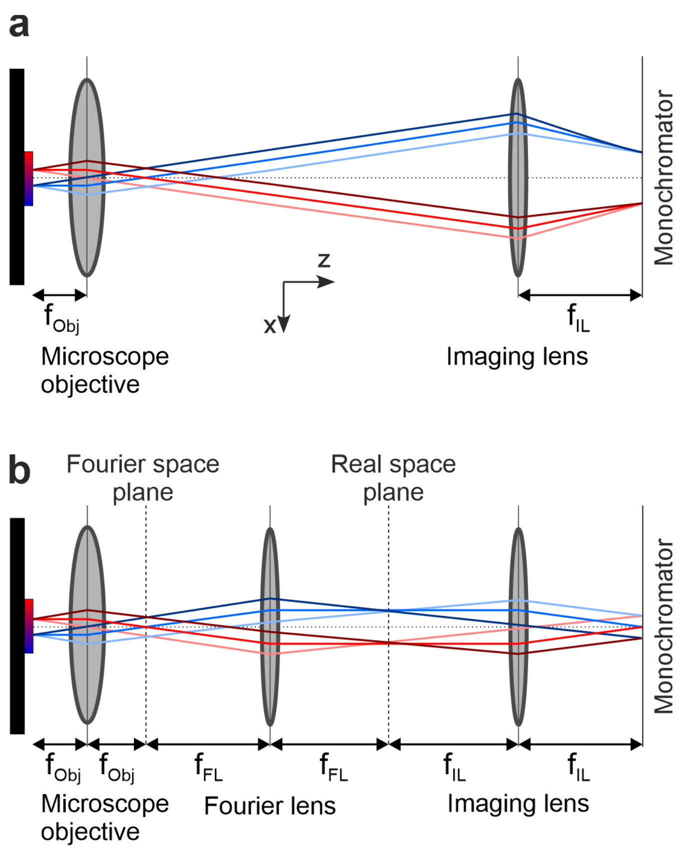


*Figure 2: Schematic of the beam path for imaging the real (a) and reciprocal (b) space of the sample onto the entrance slit of the spectrometer.*

## 3. Sample design

In the experiment, a radial stripe sample is to be investigated, the layer structure of which is shown schematically in Figure 3. The sample was prepared by molecular beam epitaxy (MBE) at the Lehrstuhl für Technische Physik at the University of Würzburg. The Bragg mirrors surrounding the active layer consist of $AlAs/Al_{0.1}Ga_{0.9}As$ mirror pairs with an optical thickness of $\lambda_{center}/4$. The lower mirror is composed of 33.5 layer pairs, the upper mirror of 27 layer pairs, in order to ensure high light confinement on the one hand and efficient sample emission through the upper mirror on the other hand. The quantum wells, consisting of $In_{0.04}Ga_{0.96}As$, are embedded in a barrier material (GaAs) and have a thickness of a few nanometers.

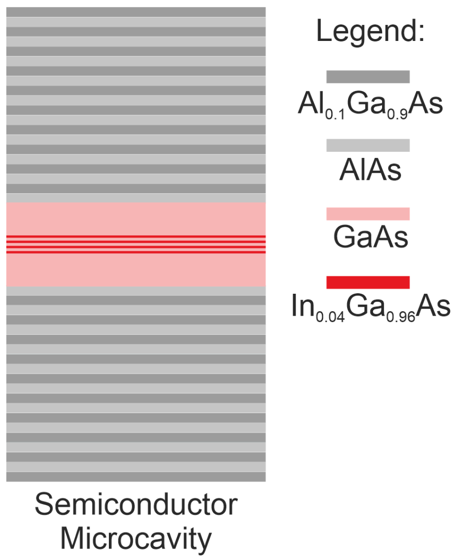


*Figure 3: Schematic of the semiconductor sample (radial stripe) investigated in the experiment.*

## 4. Measurement plan

Preparation

A) Cool down the sample mounted in the cryostat to a temperature of approx. 10-15 K.

Resolution

B) During the cooling procedure, determine the resolution of the spectrometer using a krypton spectral lamp for the three available gratings of the monochromator (150, 300, and 1200 lines) by recording the spectrum of the lamp for different slit widths (2500, 1500, 1000, 500, 250, 100, 50, 25, and 10 µm). From this, determine the maximum resolvable quality factors. Also check the spectral position of the maxima.

Uncoupled oscillators

C) Record the reflection spectrum of the radial stripe for a large negative detuning between the photon mode and the exciton mode. From this, determine the quality factor of the photonic resonance. Afterwards decide which measurement settings (grating, slit width) you want to use for the remaining measurement series.

D) Record the emission spectrum of the radial stripe at the very same position and determine from it the emission wavelength of the quantum well exciton and its full-width half maximum (FWHM).

Coupled Oscillators

E) Record angle-resolved reflection and emission spectra of the radial stripe for detuning between photon and exciton modes as close to zero detuning as possible. Fit the measured spectra using a coupled oscillator matrix. From the fit, determine the coupling strength between the quantum well exciton and the cavity photon and their spectral detuning.

F) Calculate the Hopfield coefficients from the values determined in E) as a function of the measurement angle.

G) Repeat steps E) and F) for at least two more detunings (positive and negative) between quantum well exciton and cavity photon.

H) Now select a position on the sample that has a slightly negative detuning. In the photoluminescence measurement, both the lower and the upper polariton branch should be visible. Perform a hyperspectral imaging measurement by moving the imaging lens in small steps to determine the emission kx-, ky- and energy-resolved. For further information on the settings as well as the automated procedure using LabVIEW, a short manual is available at the measurement setup.

## 5. Preparing for the experiment

Topics

Imaging of the real and the reciprocal space of an object, grating spectrometer and its resolution
Bragg mirror, stopband, central wavelength, microcavity, quality factor
low-dimensional quantum systems, quantum well, excitons
strong light matter interaction, exciton-polaritons, coupled oscillator matrix, Hopfield-coefficients
flow cryostat, Pen-Ray lamp, diode laser

Recommended literature

Kavokin, Baumberg - Microcavities (Oxford University Press, 2011)
Kavokin, Malpuech - Cavity Polaritons (Elsevier, 2003)

## 6. Software

ANDOR Solis