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Exciting and Resolving Quantum Dot Emission with Adiabatic Rapid Passage and Fabry Perot Interferometer

Master Thesis
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Technische Physik

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Abstract

This is a placeholder for the abstract. It summarizes the whole thesis to give a very short overview. Usually, this the abstract is written when the whole thesis text is finished.

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1 Introduction

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special contents, but the length of words should match the language.

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2 Quantum Dot

2.1 Processing

2.2 Properties of our dots

Table 2.1: My caption

Quantum dot emission	Energy	Frequency
Center	(1.38 to 2.07) eV	$(3.33 \text{ to } 5.00) \times 10^{14}$ Hz
Spectral range	(100 to 500) µeV	$(24.20 \text{ to } 120.90) \times 10^{9}$ Hz

2.3 Adiabatic Rapid Passage

3 Chirp

Hallo [1]

4 Scanning Fabry-Pérot Interferometer

4.1 Motivation

Resolve QD emission line.

4.2 Theory

4.2.1 Gaussian Beam

Dot-Spectra in far field is (TEM_{00}).

4.2.2 Fabry-Pérot Interferometer

The Fabry-Pérot interferometer is an optical resonator developed by Charles Fabry and Alfred Pérot. An incoming light beam will only be transmitted through the resonator consisting of two semi-transparent mirrors if it fulfils the resonance condition.[2]

4.2.3 Resonator losses

For the following discussion of the Fabry-Pérot interferometer, a two-mirror-resonator with the reflecting surfaces facing each other and air as medium in between is assumed. The time the light needs for one roundtrip is then given by [3]

$$t_{RT} = \frac{2l}{c} \tag{4.1}$$

where l is the geometrical length of the resonator and c is the speed of light in air.

The photon-decay time $\tau_c \nu$ of the interferometer is then given by

$$\frac{1}{\tau_c} = -\frac{\ln(R_1 \cdot R_2)}{t_{RT}} \tag{4.2}$$

where R_1 and R_2 are the corresponding intensity reflectivities of the mirrors.

The number of photons at frequency ν inside the resonator is described by the differential rate equation

$$\frac{d}{dt}\varphi(t) = -\frac{1}{\tau_c}\varphi(t). \tag{4.3}$$

With a number φ_s of photons at $t = 0$ the integration gives

$$\varphi(t) = \varphi_s e^{-t/\tau_c} \tag{4.4}$$

4.2.4 Resonance frequencies and free spectral range

The round-trip phase shift at frequency ν is given by

$$2\phi(\nu) = 2\pi\nu t_{RT} = 2\pi\nu\frac{2l}{c} \tag{4.5}$$

where $\phi(\nu)$ is the single-pass phase shift between the mirrors.

Resonances are visible for frequencies ν at which the light interferes constructively after one round trip. Two adjacent resonance frequencies differ in their round trip phase shift by 2π. Hence, the free spectral range $\Delta\nu_{FSR}$, the frequency difference between two adjacent resonance frequencies, can be calculated from equation (4.5)

$$2\Delta\phi = 2\pi \tag{4.6}$$

$$\Rightarrow 2\pi\Delta\nu_{FSR}\frac{2l}{c} = 2\pi \tag{4.7}$$

$$\Rightarrow \Delta\nu_{FSR} = \frac{c}{2l} \tag{4.8}$$

4.2.5 Airy distribution of the Fabry-Pérot interferometer

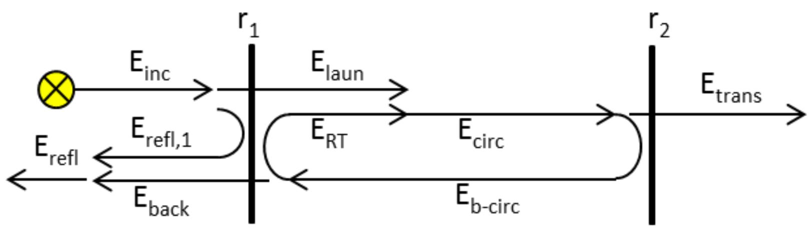

Figure 4.1: Fabry-Pérot interferometer with electric field mirror reflectivities r_1 and r_2. Indicated in this figure are the electric fields resulting from an incoming E_{inc}, the reflected field $E_{refl,1}$ and transmitted field E_{laun}. E_{circ} and $E_{circ,b}$ circulate inside the resonator, resulting in E_{RT} after one round-trip. E_{back} is the backwards transmitted field.[4]

The response of the Fabry-Pérot interferometer is calculated with the circulating-field approach [3], where a steady-state is assumed. E_{circ} is the result of E_{laun} interfering with E_{RT}. E_{laun} is the transmission of the incoming light E_{inc} and E_{RT} is E_circ after one round-trip in the resonator, i.e., after the outcoupling losses of mirror 1 and 2. Therefore, the field E_{circ} can be calculated from E_{launch} by

$$E_{circ} = E_{laun} + E_{RT} = E_{laun} + r_1 r_2 e^{-i2\phi} E_{circ} \Rightarrow \frac{E_{circ}}{E_{laun}} = \frac{1}{1 - r_1 r_2 e^{-i2\phi}} \tag{4.9}$$

where r_1 and r_2 are the electric-field reflectivities of mirror 1 and 2.

The generic Airy distribution considers only light inside the mirrors and is defined as

$$A_{circ} = \frac{I_{circ}}{I_{laun}} = \frac{|E_{circ}|^2}{|E_{laun}|^2} = \frac{1}{\left|1 - r_1 r_2 e^{-i2\phi}\right|^2} = \frac{1}{\left(1 - \sqrt{R_1 R_2}\right)^2 + 4\sqrt{R_1 R_2}\sin^2(\phi)} \tag{4.10}$$

with

$$\begin{aligned}\left|1 - r_1 r_2 e^{-i2\phi}\right|^2 &= |1 - r_1 r_2 \cos(2\phi) + i r_1 r_2 \sin(2\phi)|^2 = [1 - r_1 r_2 \cos(2\phi)]^2 + r_1^2 r_2^2 \sin^2(2\phi) \\ &= 1 + R_1 R_2 - 2\sqrt{R_1 R_2}\cos(2\phi) = \left(1 - \sqrt{R_1 R_2}\right)^2 + 4\sqrt{R_1 R_2}\sin^2(\phi)\end{aligned}$$

and additionally $R_i = r_i^2$ and $\cos(2\phi) = 1 - 2\sin^2(\phi)$.

4.2.6 Simulation

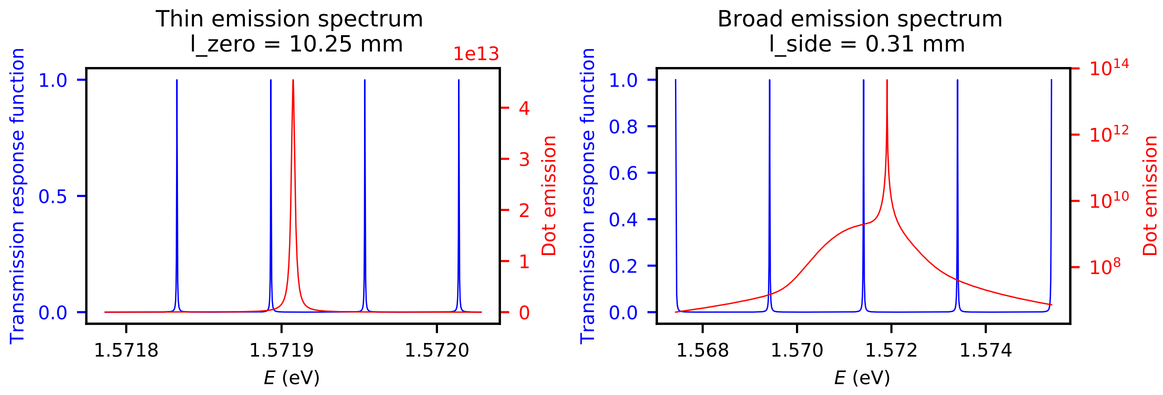

Figure 4.2:

4.3 Setup

4.3.1 Flat mirrors

4.3.2 Concave mirrors

4.3.3 Confocal setup

4.4 Measurements and Results

Appendix

Bibliography

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