Lecture Series on Principles of Lasers

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Time: **Place:**

Overview

The aim of this lecture is to give an introduction to the physical principles underlying laser operation. Starting only from basic quantum mechanics and electromagnetism, we derive the characteristics of the laser gain and the laser dynamical equations. This permits us to deduce the behavior of single-mode lasers in steady-state, transient, and pulsed regime. We also introduce the basic concepts related to laser noise. We then generalize this physics to multimode lasers dynamics, eventually allowing us to describe the mode-locked laser operation. We end up by describing the transverse characteristics of the laser intracavity electromagnetic field, illustrating the concept of mode in both stable and unstable cavities.

Lecture 1 – Laser and matter-light interaction

- 1.1 Introduction and history
- 1.2 The LASER process
- 1.3 Optical Bloch equations for a two-level system
- 1.4 Steady-state regime. Gain. Saturation
- 1.5 Laser cross section. Generalizations

Lecture 2 – Equations of the single-frequency laser

- 2.1 Bloch-Maxwell equations of the laser
- 2.2 Adiabatic elimination. Laser classes
- 2.3 Rate equations. Three- and four-level systems

Lecture 3 – Single-frequency laser in steady-state regime

- 3.1 Steady-state solutions
- 3.2 Laser frequency
- 3.3 Laser power
- 3.4 Spatial hole burning in a linear cavity

Lecture 4 – Laser based on an inhomogeneously broadened transition

- 4.1 Inhomogeneously broadened medium
- 4.2 Laser operation
- 4.3 Special case of gas lasers
- 4.4 Mode selection

Lecture 5 – Transient and Q-switched operations

- 5.1 Transient laser behavior
- 5.2 Transient operation in multimode regime
- 5.3 Q-switched laser

Lecture 6 – Frequency and intensity noises

6.1 Langevin equation for the class-A laser
6.2 Amplitude and phase noises of a class-A laser
6.3 General case and application to the class-B laser

Lecture 7 – Two frequency lasers

7.1 Self- and cross-saturation terms
7.2 Mode competition in class-A lasers
7.3 Transient behavior of a two-frequency class-B laser
7.4 Injection locking

Lecture 8 – Mode-locked laser operation

8.1 Introduction
8.2 Spectral approach to active mode-locking
8.3 Temporal approach to active mode-locking II: Haus's model
8.4 Temporal approach to passive mode-locking

Lecture 9 – Propagation and characterization of short laser pulses

9.1 Dispersion. Chirp
9.2 Pulse characterization

Lecture 10 – Optical resonators: modes and rays

10.1 Introduction: the concept of mode
10.2 Ray optics and ray matrices

Instructors

Tao Wang, he received his Ph.D. degree in physics from the Université de Nice-Sophia Antipolis, France, in 2016. From 2013 to 2016, he worked in the Institut Non Linéaire de Nice (now the Institut de Physique de Nice) as a PhD student. Since 2016, he was a post-doctoral fellow in the Institut National de la Recherche Scientifique (INRS), Canada. He currently is an associate professor in the School of Electronics and Information, Hangzhou Dianzi University, Hangzhou, China. He has published well over 30 articles in the top journals, such as Applied Physical Letters, Physical Review A, Scientific Report, Annalen der Physic, Review of Scientific Instruments, etc. His research interests include micro/nano scale laser dynamics, optical sensors based on lasers, nonlinear optics, light-matter interactions, and optical materials. E-mail: wangtao@hdu.edu.cn.
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