Wide-autoscanned narrow-line tunable system based on CW Ti:Sapphire/Dye laser for high precision experiments in nanophysics

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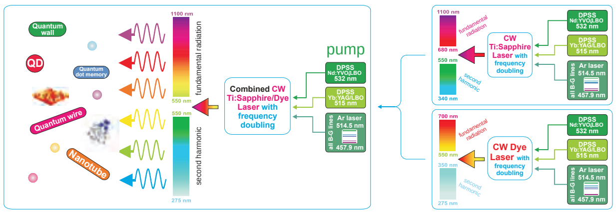
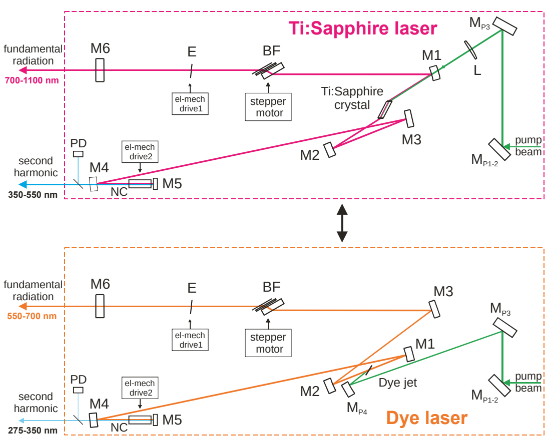
Introduction

Dye laser and Ti:Sapphire laser are characterized by ability to tune over a wide wavelength range, moreover widths of tuning ranges of these lasers are one of largest for tunable lasers.

The **idea to integrate the lasers of these types is quite natural**, this combined laser is capable to cover a wide spectral area including visible and near-infrared. It is especially advisable to make combined tunable Ti:Sapphire laser and Dye laser in the case of CW-lasers, which latter have very similar selecting elements and design (the active medium is placed between two short-focus spherical mirrors etc.) One more significant advance of integration of Dye laser and Ti:Sapphire laser into single device consists in the fact that the oscillators used to pump Ti:Sapphire laser are appropriate to pump a variety of dyes.



Experimental layout



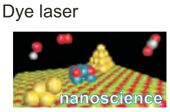
Layout of the combined CW narrow-line Ti:Sapphire/Dye laser: MP1-4 - pump mirrors, M1, M2, M4 - spherical mirrors (M1/M2: R=75 mm for Dye laser and R=100 mm for Ti:Sapphire laser), M3, M5 - flat mirrors, M6 - output coupler, BF - 3-plate birefringent filter, E – solid thin Fabri-Perot etalon, PD - photodetector, L - lens.

Application in nanoscience

Radiation linewidth: < 0.001 nm (< 1 GHz) for Ti:Sapphire laser

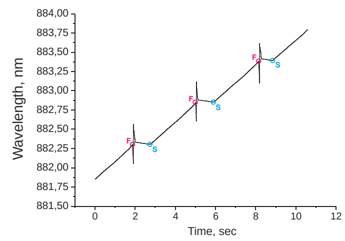
< 0.003 nm (< 3 GHz) for Dye laser

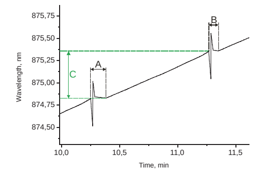
Wavelength accuracy: 0.001 nm



Parameters and modes of generation of such computer-controlled tuneable laser system are in many ways suitable for efficient solving of problems in the fields of **nano-science and nano-technology**. An important problem in this area is characterisation of semiconductor nano-particles possessing quantum-dimensional properties (**quantum dots, wells, and quantum threads**) according to their optical parameters. These quantum nano-structures exhibit quasi-atomic discrete energy spectra depending on their size and composition. For instance, typical absorption line widths of isolated quantum dots lie within **0.05–0.1 MeV (0.4–0.8 cm–1), which corresponds to 12.1–24.2 GHz**. Therefore, one is able, by means of a tuneable laser with the output line width in the vicinity of 1–2 GHz, to record such absorption lines with sufficient precision and to determine their shape. The use of three-component BF and a thin étalon in a linear CW Ti:Sa laser provides the output radiation line at the level of 1 GHz, whereas in a linear CW dye laser the radiation output line width provided by these selectors amounts to approximately 2–2.5 GHz.

Smooth scanning



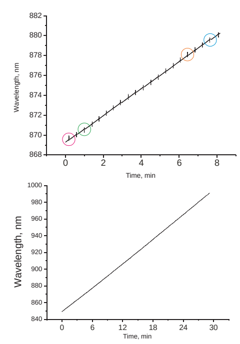


A, B - time intervals when thin etalon comes to initial position, C -smooth scanning range (~0,5 nm)

Automatic tuning of laser wavelength: symbol "F" is used to mark the end of the continuous laser output line scanning range and symbol "S" is used similarly for the beginning of the continuous scanning range, i.e. smooth scanning of the laser radiation line is carried from the wavelength marked with "S" until the wavelength marked "F". Subsequently, from "F" to "S" the étalon is reset to its initial position. For the duration of this reset process the system is not operational because during this time the end of the previous continuous scanning range is being "spliced" to the beginning of the next similar range. For the duration of this service procedure the intake of experimental data related to effects of the system's output radiation is blocked on a special signal active until the end of this procedure.

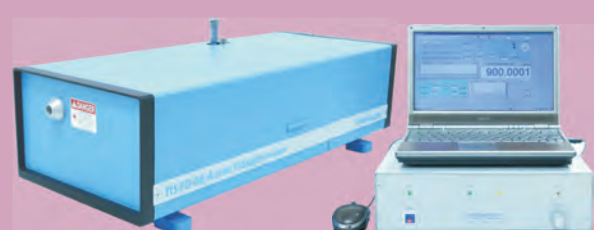
Method of quasi-smooth scanning

The new method of synchronous detuning of BF and the thin étalon we have developed works in a wide spectral range and is based on an analysis of the dependence of the laser output wavelength at the moment when the thin étalon is reset to its initial position. The laser radiation wavelength curve during this transition has the form of a derivative of a bell-shaped function. If the transmission maxima of BF and etalon do not coincide at the end of the continuous laser line scan then the laser wavelength dependence curve **will not be symmetrical with respect to the last laser output wavelength in the cycle of continuous scanning**. The degree of this dissymmetry is a measure of misalignment between the spectral position of BF and thin étalon's transmission peaks at the boundary of the continuous wavelength detuning range of the laser output. **Measurement of asymmetry degree of the laser output wavelength dependence** during the process of resetting the thin étalon into its initial position makes it possible to correct the BF position between cycles of smooth laser line scanning and to continue synchronous scanning of the two selectors in the subsequent cycle of continuous scanning of the laser output line.



Control interface

Examples of screen interface during work of the system in automatic regime.



Summary

We propose in this paper a new technique for controlling two selective elements (BF and thin étalon) of a CW tuneable laser that provides fully automatic quasi-continuous detuning of the laser output line within **ultra-wide spectral range from 275 to 1100 nm**. This technique only requires continuous control of the laser output wavelength and does not depend on additional photo-detectors or encoders for reading the position of wavelength selectors. This method may be used in various narrow-line CW lasers (solid-state, dye, hybrid fibre/bulk, etc.) in which BF and a thin étalon are used for wavelength selection. It can be also applied successfully in systems where a prism or a diffraction grating is used instead of BF filter.

The proposed technique allows relatively simple and efficient automation of quasi-continuous laser output line detuning within a broad spectral domain. Such automatically scanned laser systems are required for solving many problems in nano-science and nano-technology.