Ultra-narrow-linewidth combined CW Ti:Sapphire/Dye laser for atom cooling and high-precision spectroscopy

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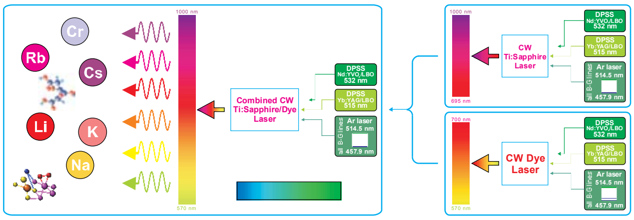
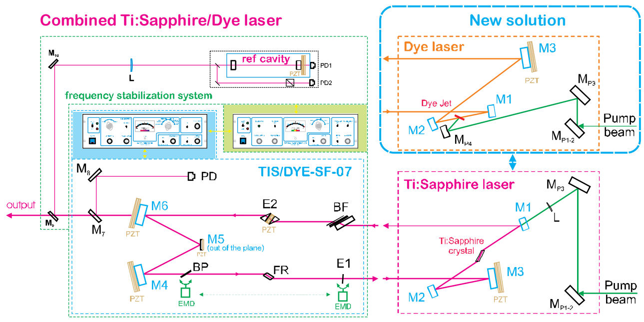
Introduction

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.

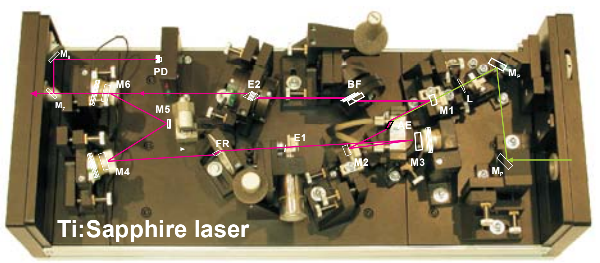


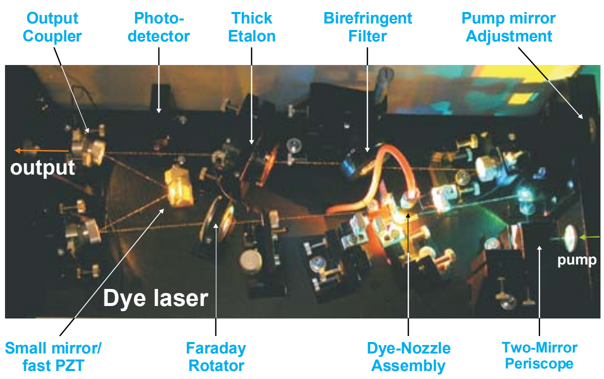
Laser configuration



Layout of the combined CW ring single-frequency Ti:Sapphire/Dye laser: M_{P1-4} - pump mirrors, M1 & M2 - spherical mirrors, M3, M4 - flat mirrors, M5 - small-mirror/fast-PZT assembly, M6 - output mirror, BF - 3-plate birefringent filter, E1 – solid thin Fabri-Perot etalon, E2 - thick Fabri-Perot etalon, FR - Faraday rotator, BP - Brewster plate, PD - photodetector, L - lens, M7-M10 - auxiliary mirrors, PZT – piezoceramic, EMD – electro-mechanical drive.

Universality of proposed configuration

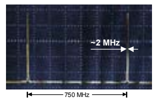




Laser frequency stabilization

In order to stabilize the frequency of the laser a stabilization system is applied which uses as a reference the transmission peak slope of temperature-controlled interferometer with FSR = 750 MHz and finesse up to 400 (typical slope width of transmission peak is about 2 MHz). In the interferometer the changing of base is accomplished only with piezoceramic (one or multiple) without using of Brewster plates with galvanic drive, temperature variations of which can significantly reduce the temperature stability of reference interferometer.

The reference interferometer is positioned beside the laser on a single optical bench to which it is attached through a vibration sink platform.



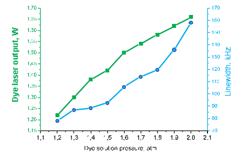
Width and drift of laser radiation line

Short-term output line width relative to the reference cavity:

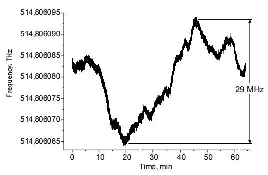
Ti:Sapphire laser: < 10 kHz rms

Dye laser: < 75 kHz with Ar laser pump,
< 50 kHz with DPSS pump

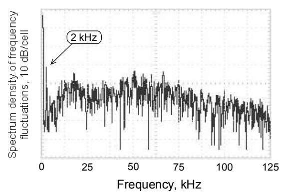
Frequency drift: < 30 MHz/hour



Dependence of the output and the radiation line width of the dye laser upon the pressure of the dye solution before the jet nozzle.

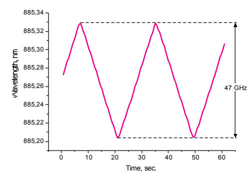


Dependence of laser frequency on time obtained with wavelength meter WS/Ultimate.

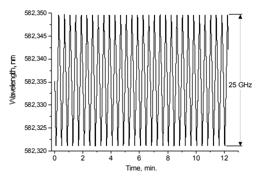


Spectral density of the frequency noise of the stabilized laser in Dye configuration, linewidth: 75 kHz rms.

Smooth frequency tuning range



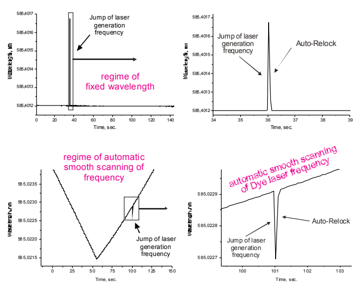
Automatic smooth scanning of Ti:Sapphire laser frequency in the free-running generation mode (regime of passive frequency stabilisation).



Automatic smooth scanning of Dye laser frequency in regime of active frequency stabilisation.

Frequency stabilisation system with Auto-relock function

When Auto-Relock function is active the system keeps track of the control voltages on the PZT actuators and, as these voltages reach the limit, it automatically decrements (or, correspondingly, increments) this control voltage until the laser generation frequency returns back onto the slope of the interferometer transmission peak. Further, the laser frequency is automatically locked by the stabilisation system



Summary

Presented is a new combined single-frequency ring laser with universal design that allows efficient use of both Ti:Sapphire crystal and a dye jet as the active medium of the laser. For the first time such combined laser design was implemented in a horizontal resonator scheme, thereby providing improved position stability of optical elements and added convenience of use. The short-term line width without the frequency stabilisation is less than 5 MHz (Ti:Sapphire) and < 10 MHz (dye laser), smooth scanning range without the frequency stabilisation is more than 47 GHz (Ti:Sapphire) and > 50 GHz (Dye). With the frequency stabilisation on a special high-finesse reference interferometer with thermostabilisation the line width is reduced to less than 10 kHz (Ti:Sapphire laser) and down to ~ 50 kHz (dye laser), output frequency drift being less than 30 MHz/hour, smooth scanning range is more than 19 GHz (Ti:Sapphire) and > 25 GHz (Dye).