Long-term frequency stabilisation of a CW single-frequency laser using a high-precision wavelength meter

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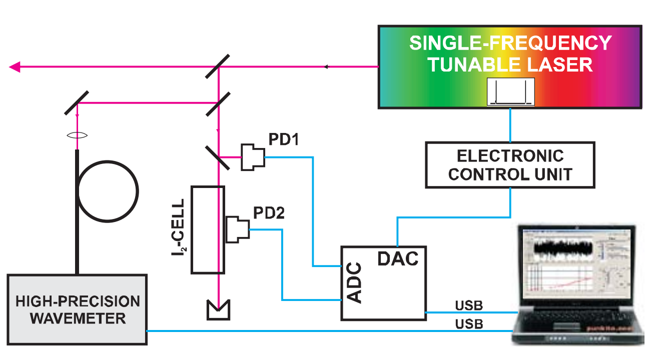
Introduction

Stabilisation of laser generation frequency by a wavemeter is, in some aspects, similar to stabilisation of laser generation frequency with a reference interferometer because analogous interferometers may be used in wavemeters. However, a stabilisation system with the use of a wavemeter has a number of specific features:

1. This system must have a digital (or computer-based) part because the laser radiation wavelength is obtained as from digital processing of data on relative position of interference fringes produced by the stabilised laser and those produced a reference source, which may be built into the meter or a separate unit (in the latter case the data on interference fringe position for the reference laser are stored in memory and then repeatedly used);
2. Because of the digital part this system is slower in comparison with analogue ones;
3. In this system it is possible to lock the laser radiation frequency to a specified absolute value in contrast with a system that locks the laser output frequency onto a transmission peak (or peak slope) of the reference interferometer where frequency referencing is relative.

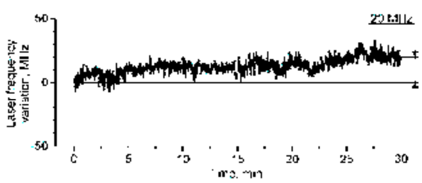
Experimental layout



Experimental layout: PD1, PD2 - photo-detectors; DAC - digital-to-analogue converter, ADC - analog-to-digital converter; PC - computer, USB - USB interface connexion.

I_2 absorption line

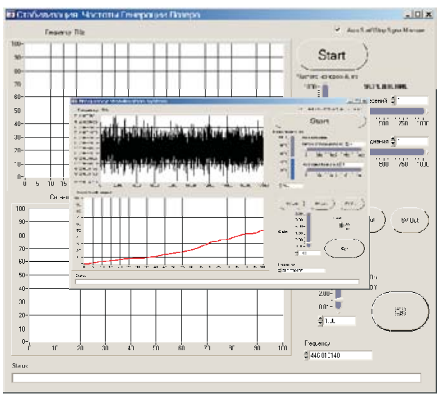
We demonstrate the dependence of the laser output frequency upon time in the stabilised mode, which was recorded from the I_2 absorption line as outlined before. This dependence has a certain slope which reveals a residual long-term drift in the wavelength meter readings amounting to approximately 20 MHz over 30 minutes or 40 MHz/hour. This parameter may be reduced several times down to < 10 MHz/hour level if continuous calibration of the wavelength meter is used.



Temporal dependence of the output frequency of CW single-frequency ring Dye laser in the frequency stabilisation mode registered with an I_2 absorption line.

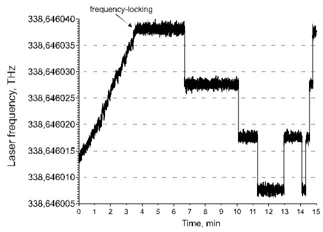
Computer control

For long-term stabilisation of the laser generation frequency with wavelength meter WS/8 a computer application was developed that emulates an analogue system of laser output frequency stabilisation. The application is based on LabWindows and has all necessary control and adjustment functions inherent in an analogue system: adjustment of the error signal gain, error signal phase switch, adjustment of the feed-back ring response time, monitoring of the error signal and the laser output wavelength. In the application program it is necessary to set the reference radiation wavelength (otherwise it is set to the laser output wavelength at the moment of system activation) and then the program generates an error signal as the current output wavelength walks off the reference value.



New! Computerised real-time control of laser radiation frequency

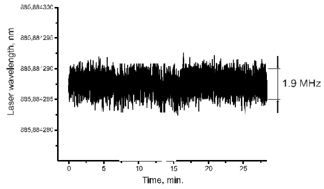
During the experiments conducted on stabilisation of the output radiation frequency of a CW single-frequency ring Ti:Sapphire laser not only the long-term drift of the output radiation frequency was studied (which is approximately the same as that for the dye laser) but also the possibility to adjust the set frequency value in certain limits without deactivation of the stabilisation system. This possibility was experimentally proven within the range of continuous detuning of the laser output frequency. Figure illustrates controlled adjustment of the generation frequency of the Ti:Sapphire laser: the initial slanted curve (3.5 min) corresponds to drift of the laser output frequency in unstabilised mode at the rate of ~ 430 MHz/hour. After that the frequency stabilisation system is engaged and at various intervals the set frequency value is changed, the stabilisation system adjusting the laser output frequency to coincide with the new value. The figures demonstrate that the laser output frequency can be automatically set to different specified values to a precision of several MHz.



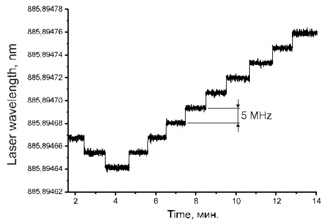
Dependence of output frequency of a CW single-frequency ring Ti:Sapphire laser upon time in the frequency stabilisation mode and with changing set frequency values. Initial slope on the plot (0–3.5 min) corresponds to generation frequency drift of the laser with the stabilisation system disengaged. Further on, the laser output frequency is set to different values through the controlling software.

Ti:Sapphire laser

Wavemeter



Plot of wavelength radiation of CW single-frequency Ti:Sapphire laser versus time with the wavelength automatically stabilised to the absolute value of 885,884287 nm

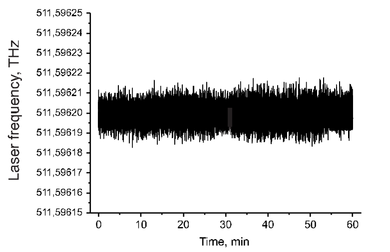


Dependence of output frequency of a CW single-frequency ring Ti:Sapphire laser upon time in the frequency stabilisation mode and with changing set frequency values. The laser output frequency is set to different values through the controlling software.

Dye laser stabilisation

The laser output frequency was in this case locked to the value 511.59620 THz. Registered frequency excursion around the set value are within ± 10 MHz over more than 1 hour, the line width of the laser radiation output being ~10 MHz.

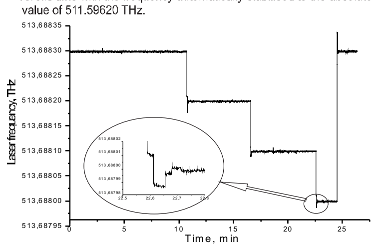
It should be pointed out that the time dependence of the laser generation frequency given here was recorded with the help of the same wavelength meter as was used to stabilise the laser output frequency. In case the wavelength meter has its own long-term read-out drift, such graph of the output laser frequency versus time will also include this drift. (Look I_2 absorption line)



Plot of generation frequency of CW single-frequency ring dye laser *versus* time with the frequency automatically stabilised to the absolute value of 511.59620 THz.

Figure illustrates controlled adjustment of the generation frequency of the dye laser: The frequency stabilisation system is engaged for 10 minutes to the absolute value of 513,68830 THz and after that at intervals 100 MHz follows to new frequency. Final wavelength corresponds again with initial wavelength.

In the zoom window you can see how stabilisation system adjusts the laser output frequency to new value.



Dependence of output frequency of a CW single-frequency ring dye laser upon time in the frequency stabilisation mode and with changing set frequency values.

Summary

Digital systems for correction of long-term drift in laser radiation frequency that utilise high-precision radiation wavemeters with optical fibre input open new opportunities for controlling laser spectral parameters. These systems feature the possibility to correct the laser radiation wavelength from time to time, for instance, once every few seconds or minutes. Such periodic correction allows the system to control several lasers, radiation from which can be sequentially guided into the wavemeter through an optical multiplexer.

Moreover, the distance between the control system and the operated laser may be quite long (hundreds of metres and more) since the radiation is guided to the wavemeter through an optical fibre and the correction signal can be transmitted to the laser, for example, over the local network or Internet. When periodically corrected for spectral position of radiation line of a single-frequency laser, such system can be efficiently operated remotely. For instance, one high-precision wavemeter may be used for simultaneous correction of long-term drift of radiation lines from multiple lasers installed in different labs within one building.