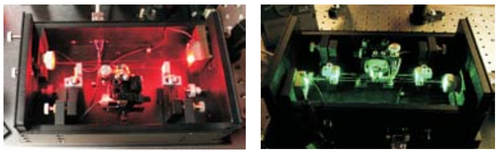
Resonant doubler with a 2-THz automatic quasi-smooth scan range for widely tunable CW single-frequency lasers

S.Kobtsev, Novosibirsk State University; V.Lunin, Tekhnoscan JSC

SPIE Photonics WEST
LASE 2007 Lasers and Applications in Science and Engineering

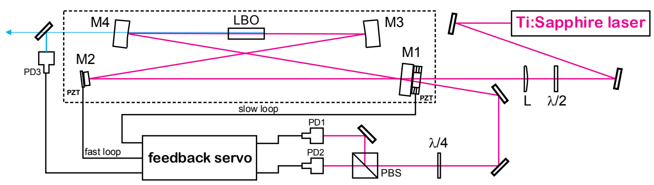
Introduction

Resonant high-Q frequency doublers of CW laser radiation are widely used for generation of radiation in UV and visible spectrum ranges. In comparison with relatively simpler doubling technology which uses PPLN crystals and fibres frequency doubling in an external cavity is capable of delivering substantially higher output powers of the second-harmonic radiation. In combination with a single-frequency tuneable laser such a resonant frequency doubler efficiently widens the working spectral range into the short-wavelength domain.



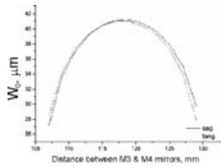
Smooth detuning of the doubled radiation frequency is performed by continuous adjustment of the doubler cavity length driven by a PZT-mounted mirror. Typically, such PZT provides continuous detuning range of the second-harmonic radiation on the level of several to tens of GHz. This limitation is related only to the maximum possible mirror travel in the doubler cavity that can be provided by the actuators. The continuous tuneability range of the second-harmonic radiation which can be equal to, say, 5 GHz or even 50 GHz is considerably narrower than the spectral width of phase matching in the crystal, which may be as broad as 1 THz. This means that because of relatively broad spectral width of phase matching in the non-linear crystal continuous (or quasi-continuous) detuning of the doubled radiation frequency is possible within a range of about 2 THz with unchanged position of the non-linear crystal.

Doubler configuration

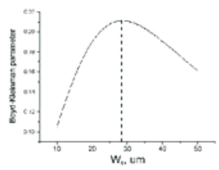


Schematic design of the Resonant Frequency Doubler: M3, M4, concave mirrors (R=100 mm); M1, input coupler, slow-PZT-driven mirror; M2, fast-PZT-driven mirror; PBS – polarization beamsplitter cubes; PD1, PD2, photoreceivers of stabilization system; PD3, control photoreceiver; L – mode-matching lens

Calculated parameters

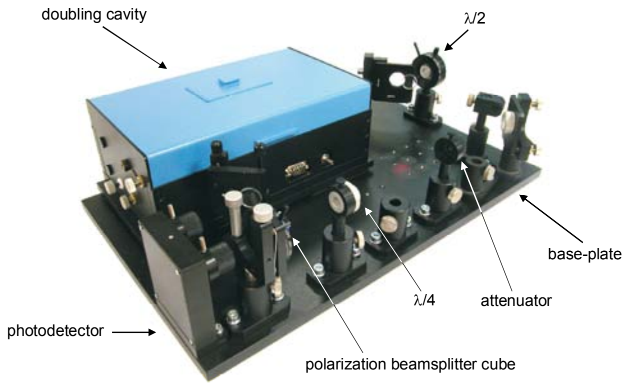


Dependences of beam waist radius W_0 in used LBO crystal on the distance between spherical mirrors.



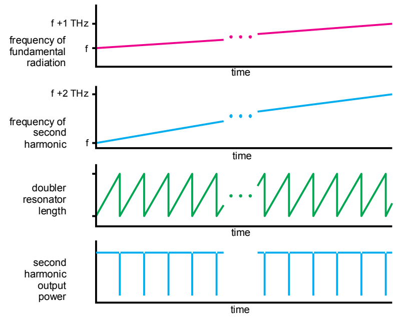
Calculated Boyd-Kleinman parameter for used nonlinear crystal is given as a function of beam waist radius W_0 for fundamental harmonic of radiation inside the crystal.

Frequency doubler arrangement



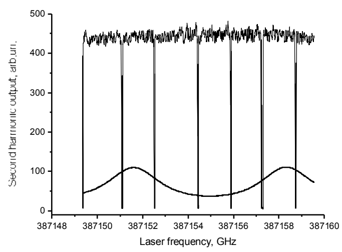
Automatic quasi-continuous scanning

In the diagrams we illustrate the process of automatic quasi-continuous detuning of the resonant frequency doubler. At moments when the resonator retracts to the initial position before beginning each cycle of continuous scanning, a brief drop in the output power of the second-harmonic radiation is observed. For this short duration the system of experimental data acquisition may be suspended by a signal from the electronic control unit of the frequency doubler. This is why for the data acquisition system frequency detuning will be smooth over a very wide spectral range, the second-harmonic output power in different cycles of continuous detuning remaining constant (the lower chart).



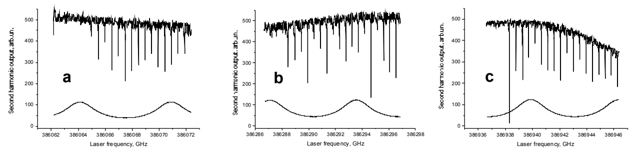
Diagrams demonstrating the process of automatic quasi-continuous tuning of the resonant frequency doubler synchronously with the frequency of the fundamental radiation within a wide spectral range. Each cycle of resonator length adjustment on the second diagram below corresponds to continuous frequency scan of the second harmonic radiation.

Re-locking process



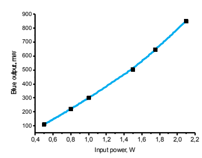
An experimental dependence of the second-harmonic output power in a cycle of continuous scanning of the laser upon frequency is shown in figure within the range from 387.1493 to 387.1588 THz. Studies were carried out with the use of single frequency Ti:Sapphire laser 899-29 Ring Autoscan II with the ability to automatically and quasi-smoothly scan the output frequency within a range in excess of dozens of THz, the continuous scan-ning range of this laser being ~10 GHz. Vertical lines in figure correspond to momentary dips in the output power of the second-harmonic radiation each time when the doubler cavity is re-locked to frequency of fundamental input radiation. Also given in figure is simultaneously registered transmission function of the wavelength meter etalon (FSR = 6.8 GHz). As the fundamental frequency was continuously detuned by 9.5 GHz the second-harmonic frequency was quasi-continuously (with frequency re-locked 6 times) detuned by 19 GHz.

Δω: 1-THz → Δ2ω: 2-THz



Experimental dependencies of the second harmonic output power upon the wavelength of the fundamental radiation: Figs. a and b correspond to automatic quasi-continuous scanning of the frequency doubler approximately in the beginning of the 1-THz domain (Fig. a) and within a spectral range about ~ 0.3 THz from the beginning (Fig. b); Figs. c illustrates the behaviour of the second harmonic output power when the fundamental wavelength approaches the edge of the phase matching domain of the non-linear crystal.

Power of blue output



A typical dependence of generated by developed doubler second harmonic power on power of input radiation at 800 nm produced by Ti:Sapphire laser.

Output power of the second-harmonic radiation in foregoing figures are given in arbitrary units, however the efficiency of the second harmonic generation in the developed doubler is sufficiently high and exceeds 40% at the input power of 2 W.

In the experiments we used also novel non-linear optical crystal BIBO (6-mm-long, produced by Foctek). By using this crystal in an external resonator a stable single-frequency generation of the second-harmonic radiation was achieved with the output power of 270 mW at the wavelength of 425 nm. Conversion efficiency is as high as 36%.

Summary

In the present work, demonstrated for the first time is automatic quasi-smooth scanning of an resonant doubler cavity synchronously with the frequency of a CW auto-scanned Ti:Sapphire laser within a 1-THz frequency range (2 THz for second harmonic), which is limited only by the spectral acceptance bandwidth of non-linear crystal. Significant (more than by an order of magnitude) widening of the synchronous scanning range was achieved owing to the suggested method of automatic re-locking of the external cavity.

In case of critical phase matching it is possible to extend this range by automatic adjustment of the position of the non-linear crystal. However, changing the position of the non-linear crystal also requires re-alignment of the resonator itself. In case of non-critical phase matching automatic adjustment of the non-linear crystal following the wavelength of the fundamental input radiation may be done by adjusting its temperature. In this case the total range of automatic quasi-continuous detuning of the doubled radiation frequency may be only limited by the possibilities of changing the frequency of the fundamental radiation.