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► **To cite this version:**

Rezki Bechecker, Léo Guiramand, Anna Martinez, Said Idlahcen, Jonathan Houard, et al.. High-intensity single-cycle THz source driven by a high-power fiber laser. CLEO Europe 2023 - Conference on Lasers and Electro-Optics Europe, Jun 2023, Munich, Germany. 10.1109/CLEO/Europe-EQEC57999.2023.10231792 . hal-04357976

HAL Id: hal-04357976

<https://hal.science/hal-04357976>

Submitted on 3 Jun 2024

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High-intensity single-cycle THz source driven by a high-power fiber laser

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High-intensity THz sources driven by ultrafast lasers are attractive for a wide range of applications such as time domain spectroscopy, molecular dynamics and THz-matter interactions in the nonlinear regime, to cite a few. Recent advances in the development of high-average power ytterbium lasers has enabled the development of high-repetition rate THz-sources using different generation schemes. The best performances have been reached in a two-colour plasma generation setup driven by a state-of-the-art Yb fibre laser system producing 640 mW THz average power at 500 kHz repetition rate [1]. However, this facility is complex and expensive as it implies few-cycle pump pulses with high average powers. The second promising approach for high power THz generation is based on optical rectification in lithium niobate (LiNbO₃) nonlinear crystals [2]. In particular, it has been demonstrated that optimization of the pump pulse duration in a tilted-pulse front pumping scheme in lithium niobate using a step-stair echelon is a good approach for optical-to-THz conversion efficiency scaling [3-4]. High-intensity single-cycle THz transients with 74 mW average power and 400 kV/cm peak intensity have been thus produced using a 10W-class pump laser delivering 10W average power at 25 kHz [4].

In this contribution, we specifically explore the repetition rate scaling of this approach. Our THz source is driven by an ytterbium-fibre-based chirped-pulse amplifier system (from AFS GmbH). The system delivers ultrashort pulses of 300 fs duration with a maximum energy of 240 μ J at 330 kHz. A THz generation scheme based on optical rectification in a LiNbO₃ prism combined with a stair-step reflective echelon for tilting the pump pulse front is exploited. To ensure phase matching between the pump and THz pulses, a set of two lenses is used to image the echelon mirror on the facet of the nonlinear crystal. The emitted THz radiation is collected by an off-axis ellipsoidal mirror. It is then collimated and refocused onto the electro-optics sampling (EOS) detection stage through a pair of off-axis parabolic mirrors. The EOS detection uses 80 fs probe pulses obtained after compressing the pump-pulses in a fiber-based post-compression stage.

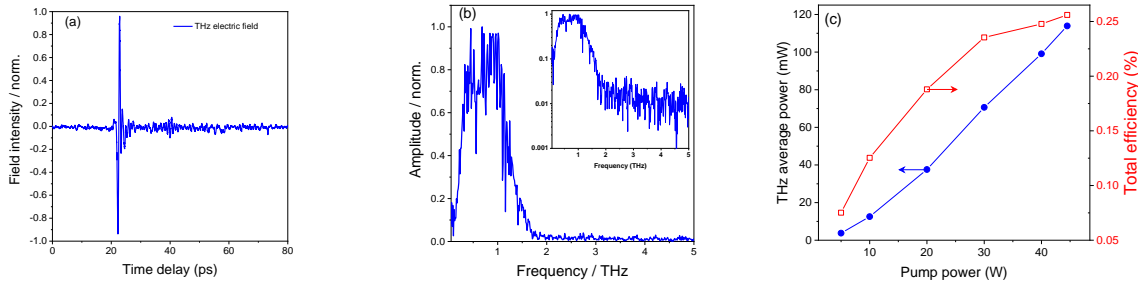


Fig. 1 Output performances of our LiNbO₃-based THz source at 205 kHz repetition rate: single-cycle THz pulse measured with the EOS setup (a), spectrum retrieved by Fourier-transforming the EOS trace (b) and output power and conversion efficiency evolution versus pump power (c).

The typical temporal trace of the generated THz pulses is given in Fig. 1(a). Single-cycle transients with about 800 fs duration are obtained. The corresponding spectrum is centred at 0.8 THz with about 1 THz width (FWHM). By optimizing the pump beam size on the LiNbO₃ crystal, we measured a THz power of 114 mW for 44.5 W pump power at 205 MHz repetition rate, corresponding to a total optical-to-THz efficiency of 0.25%. The electric field intensity of the THz radiation focused with a 50 cm focal length mirror is estimated to 450 kV/cm indicating that this approach is very appealing for building intense and powerful compact THz-sources. Further power scaling is expected by optimizing the pump pulse parameters (pulse duration and contrast) as well as the THz-generation conditions.

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