Efficient Generation of Intense Broadband Terahertz Pulses with Low-cost Quartz

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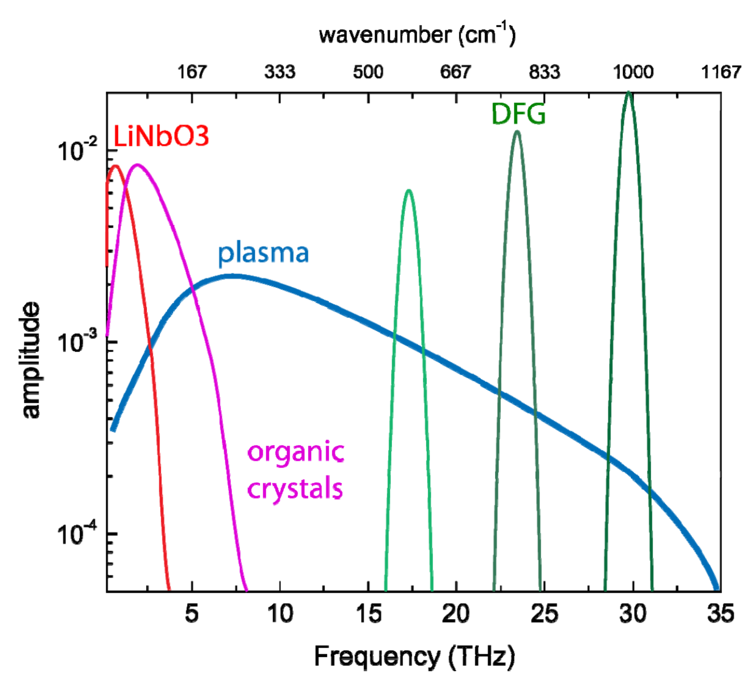
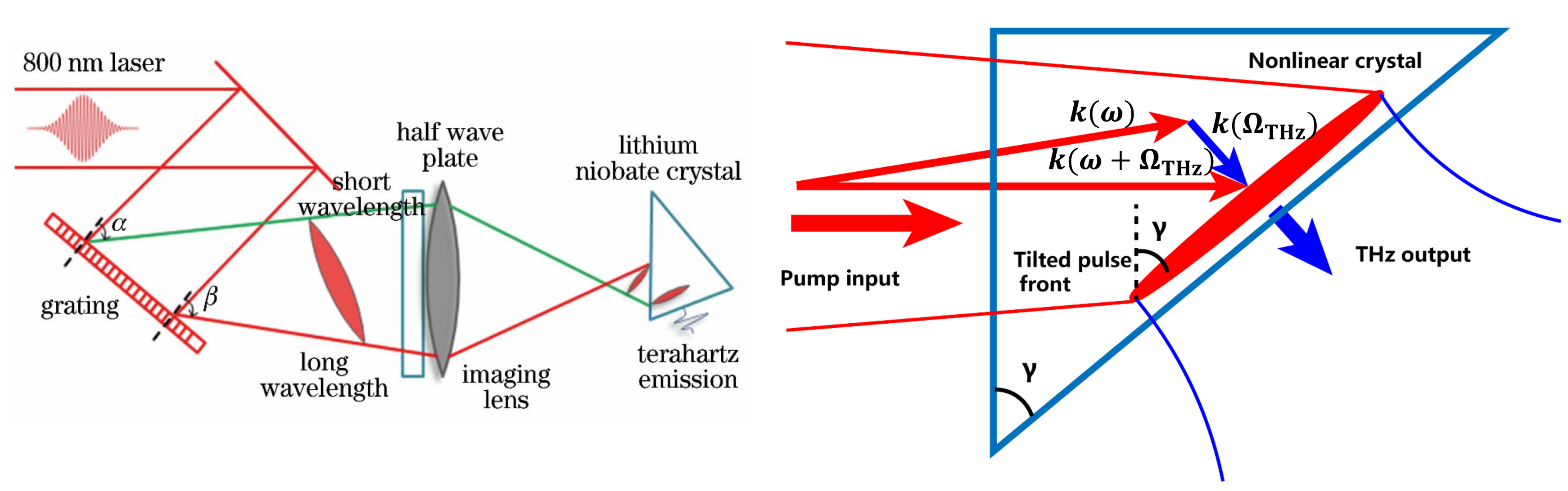
The intense terahertz (THz) pulses facilitate the observation of various nonlinear optical effects and manipulation of material properties. In this work, we report a convenient approach that can produce strong broadband terahertz pulses with center frequency tunable between 2-4 THz. The coherent THz light source with pulse energy of 1.2 microjoule can be generated from a low-cost crystalline quartz pumped by an ultrashort tilted wave-front pulse. Thanks to the wide transparent spectral window and high damage threshold, our theoretical analysis and experiment show that the optical rectification in quartz is as efficient as that in $LiNbO_3$, but covers much broader spectral range. This work not only provides the light source that is urgently needed for nonlinear THz spectroscopy beyond 1 THz, but offers an alternative route in the selection of nonlinear optical crystals for optical frequency conversion.

I. Introduction

New Terahertz Gap: 2-15THz



Tilted Pulse Front (TPF)

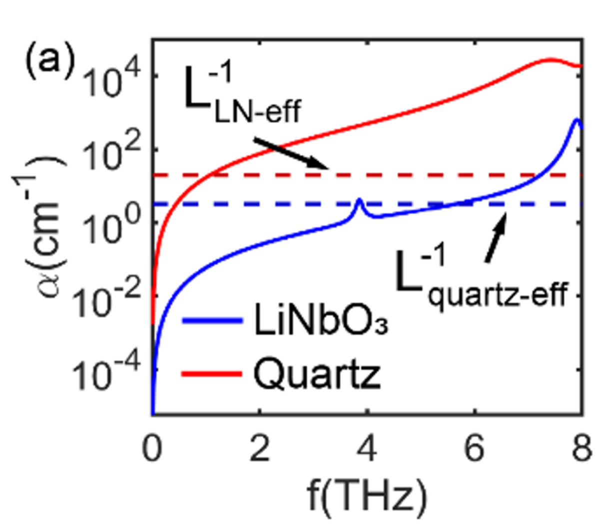


$$k(\omega+\Omega)-k(\omega)=k(\Omega) \qquad n_{THz}^{ph}\cos(\gamma)=n_{v}^{gr}(\omega_0)$$

The advantages of Quartz over $LiNbO_3$

For THz generation in TPF scheme, quartz has following advantages over LN:

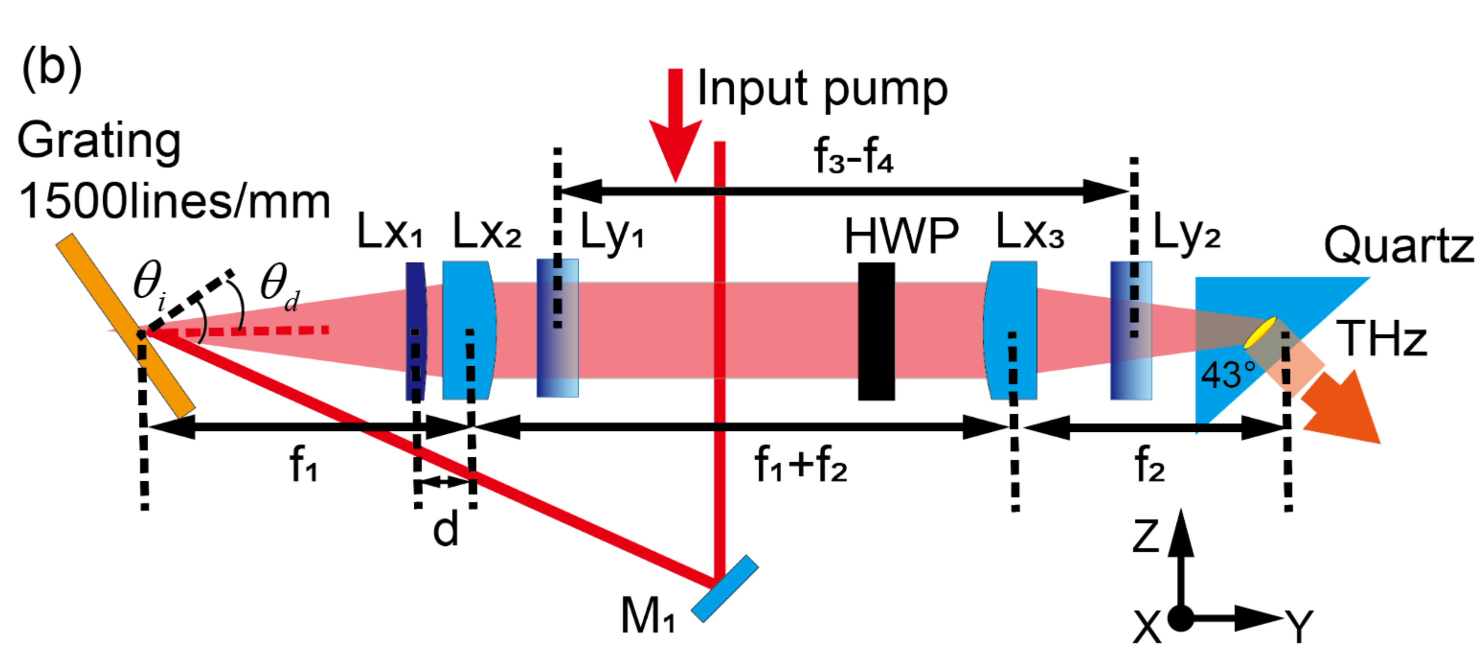
(1) Weaker absorption and wider transparent window
(2) Lower dispersion of TPF angle
(3) Smaller TPF angle leading to smaller angular GVD, leading longer L_{eff}
(4) Smaller intrinsic GVD
(5) Higher laser-induced damaged threshold
(6) Lower cost



$$E_{THz} \propto \omega_{THz} d_{eff} I L_{eff} t_{THz} / n_{THz}$$

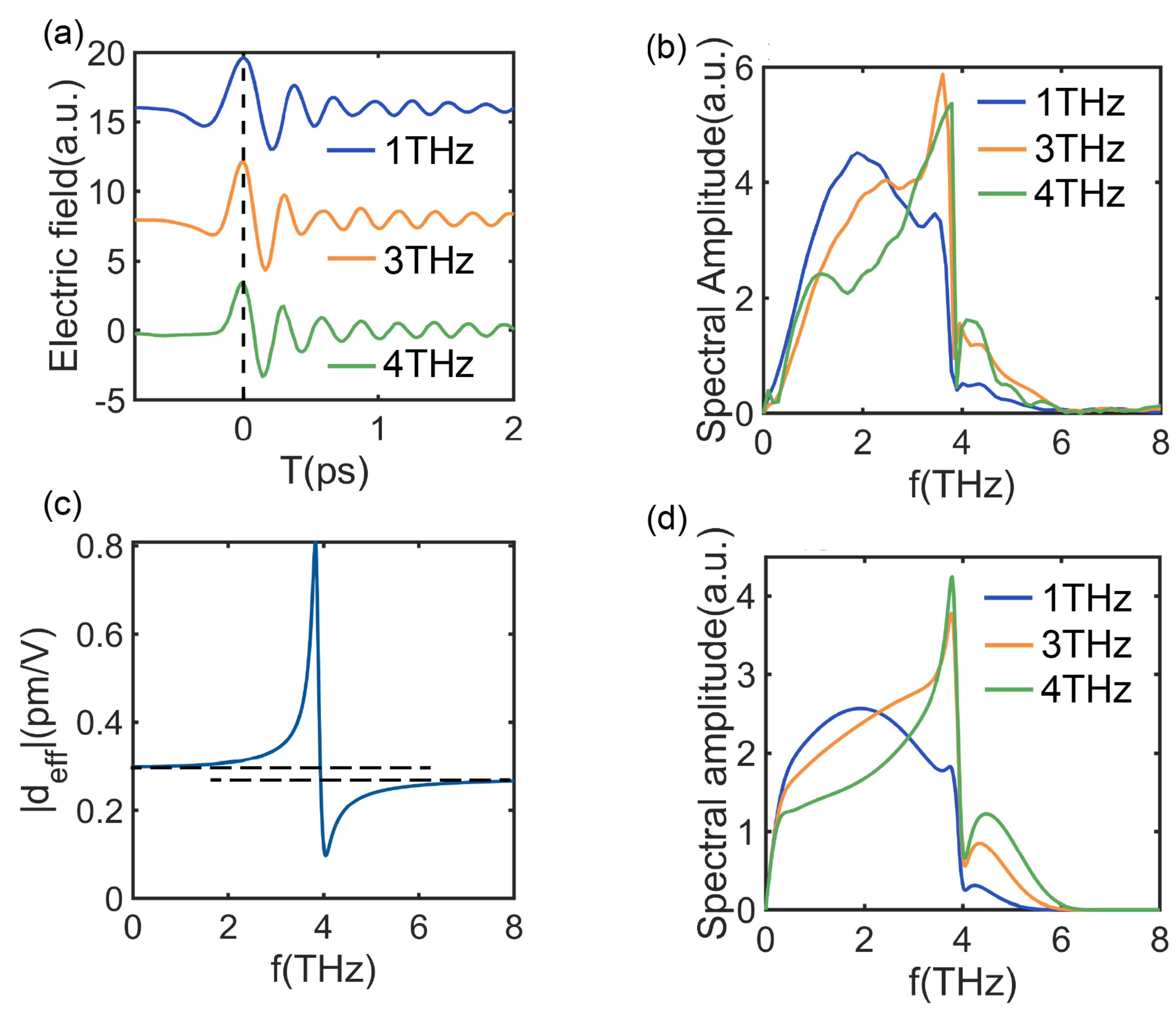
Material	d_{eff} (pm/V)	I (J/cm^2)	γ(deg)	t_{THz}	L_{eff} (mm)	E_{THz}(a.u.)
$LiNbO_3$	168	0.025	63.2	0.74	0.5	0.16
Quartz	0.3	0.25	42.4	0.93	3	0.23

II. Experiment Setup

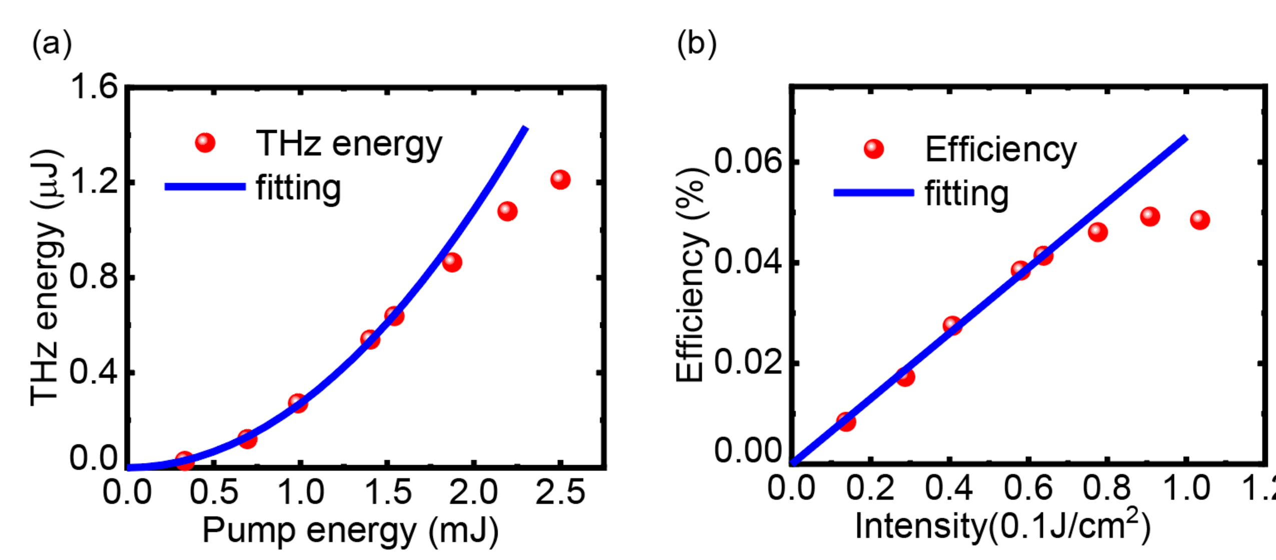


III. Experimental result

Temporal profile and spectral amplitude

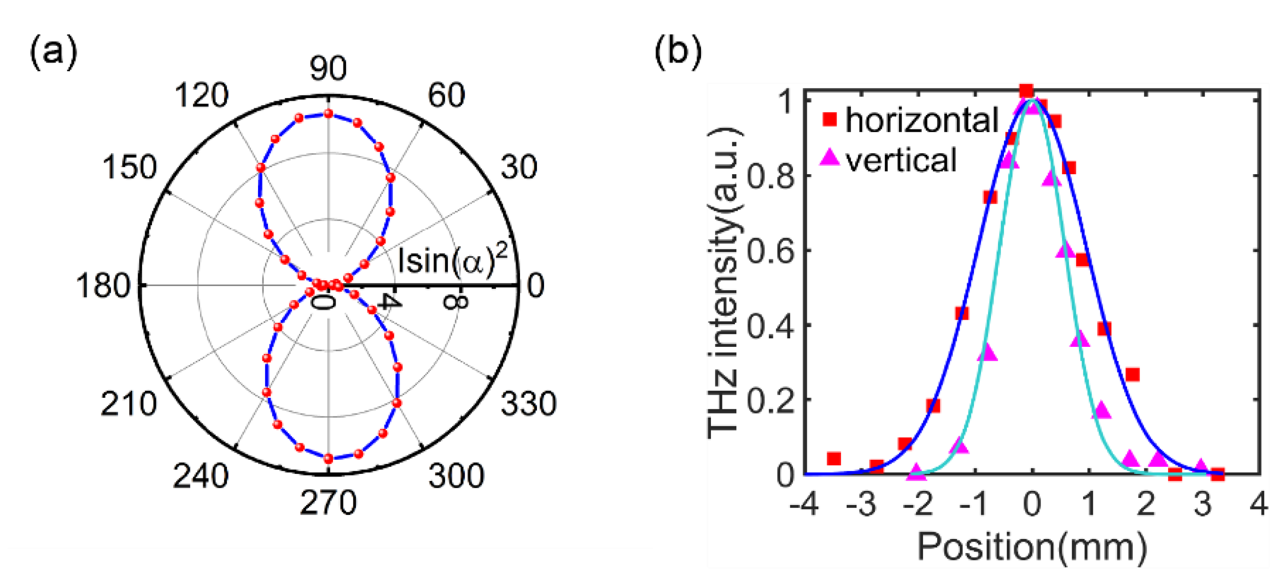


Energy per pulse and conversion efficiency



THz pulse energy:1.2μJ Conversion efficiency:0.05%

THz polarization and spatial profile



Electric field:350kV/cm

IV. Conclusion

we have reported a new method for generation of intense high-frequency terahertz pulses. Instead of choosing a nonlinear crystal with large $\chi^{(2)}$, other nonlinear crystals with high damage threshold and wide transparent window may also be efficient THz emitters. As a demonstration, we used tilted pulse front scheme to pump a wedge-shape α-quartz crystal by 2.5mJ 36fs 800nm NIR pulse with transient intensity of $0.1J/cm^2$. The THz radiation with pulse energy up to **1.2 μJ** can be obtained that covers 0-6 THz with center frequency tunable from 2-4 THz. The energy conversion efficiency up to **0.05%** was obtained for the 36 fs pump, but may reach beyond **0.12%** if a 100fs pump pulse is used accordingly to our calculation.

Reference:

1.吴晓君 et. al. 基于倾斜波前技术的高能强场太赫兹辐射脉冲源, 中国激光, vol 46, No.6 June 2019
2. J. A. Fulop, L. Palfalvi, G. Almasi, and J. Hebling, Design of high-energy terahertz sources based on optical rectification, 7 June 2010 / Vol. 18, No. 12 / OPTICS EXPRESS 12311-12327,