Observation of terahertz birefringence in a β-BaB_2O_4 Crystal

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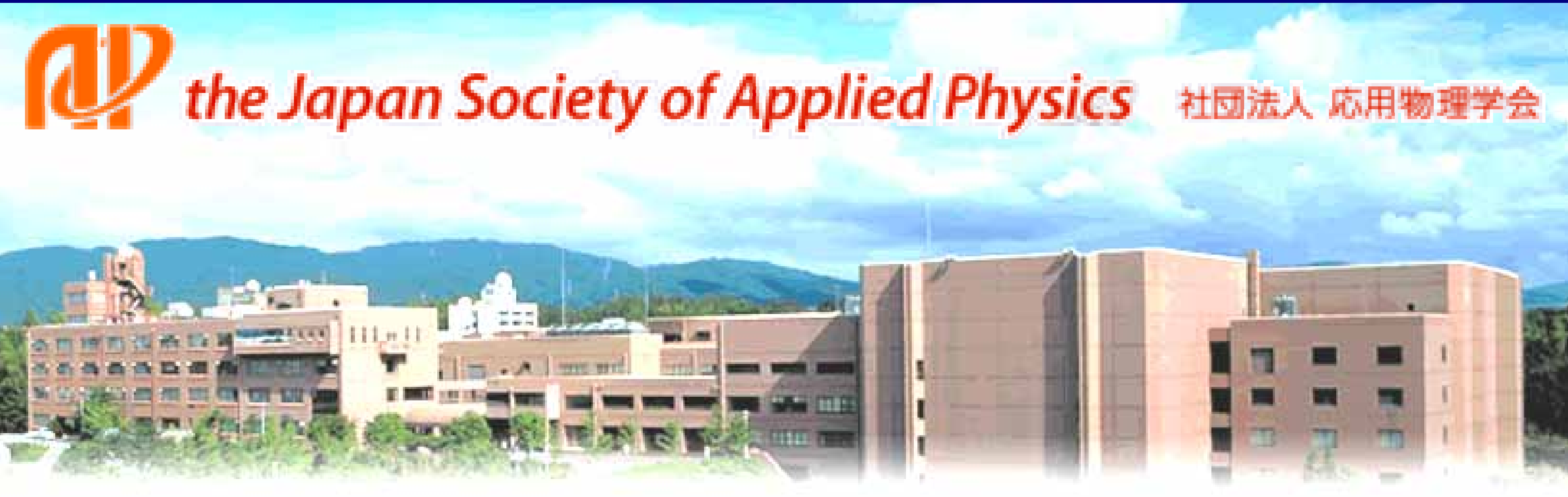
Institute of Laser Engineering. Osaka University [1], The Graduate University for Advanced Studies[2], Institute for Materials Research, Tohoku University [3]



Introduction and Motivation

1. Kawase, Minamide, Ito, et.al., have previous demonstrated tunable, 0.7-2.4 THz wave parametric generator using $LiNBO_3$.

2. Tanabe, Nishizawa, et.al., have also demonstrated a 3- 7 THz tunable THz source using GaP.

   These designs produce high-power THz radiation but have ns-wide THz emission pulse widths.

3. We have previously demonstrated high B-field enhanced, surface-illuminated InAs wafer emitter, capable of producing picosecond THz transient pulses.

4. $LinNBO_3$ and GaP are excellent THz nonlinear optical materials but we intend to investigate other materials that can be utilized complementarily with the THz emission spectrum of InAs.

5. We initiate this work by investigating the THz birefringence properties of BBO crystal.

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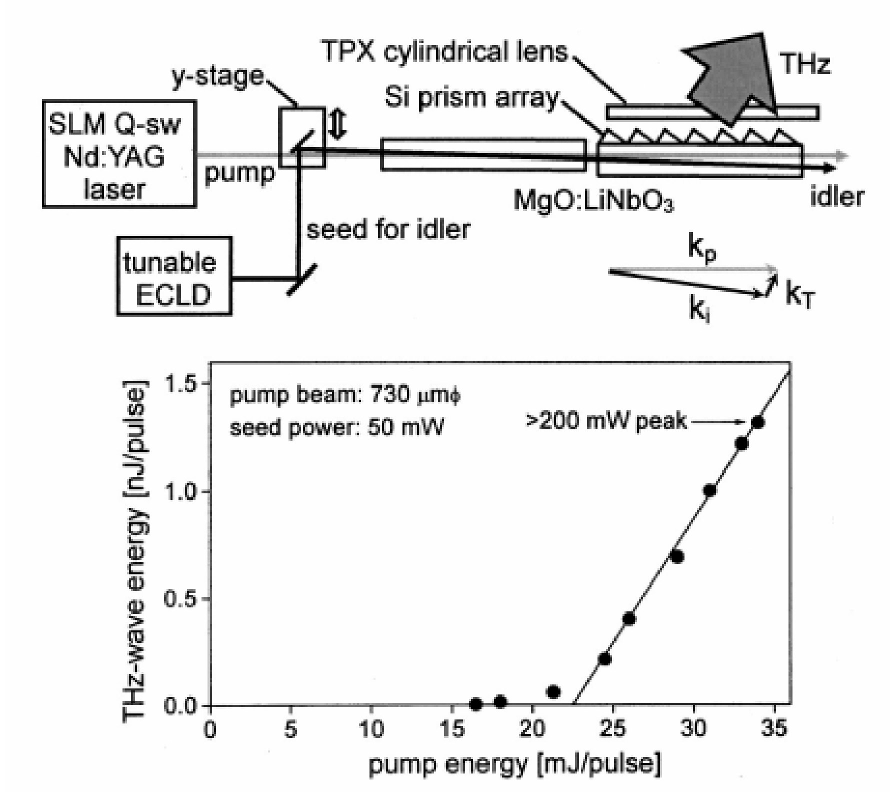

The figure showing the complex experimental setup for the THz parametric generator (TPG) . The TPG gain media consisted of two serial nonlinear crystals MgO:LiNbO$_3$. An array of seven Si-prism couplers wasplaced on the y surface of the crystal for efficient coupling of the THz wave. The idler and THz-waves were generated simultaneously in a direction that satisfied noncollinear phase-matching conditions. The pump used was a Q-switched Nd:YAG laser (1064 nm). A continuous-wave SLM-tunable diode laser (1.066–1.074) nm was used as an injection seeder for the idler. The incident angle of seed was rotated, when necessary, by a mirror on a y stage.

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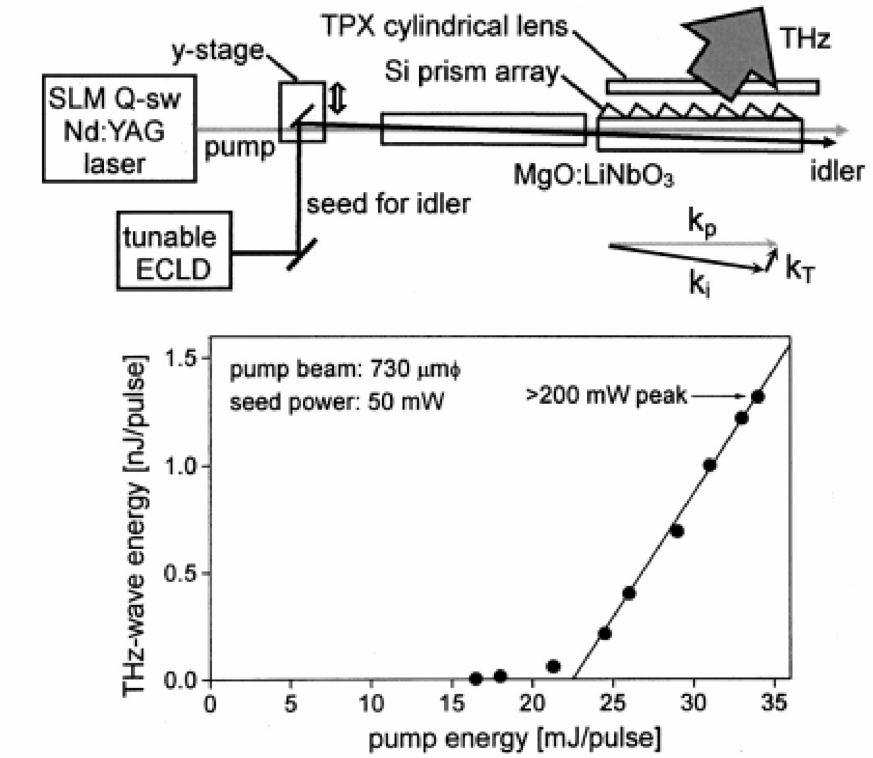

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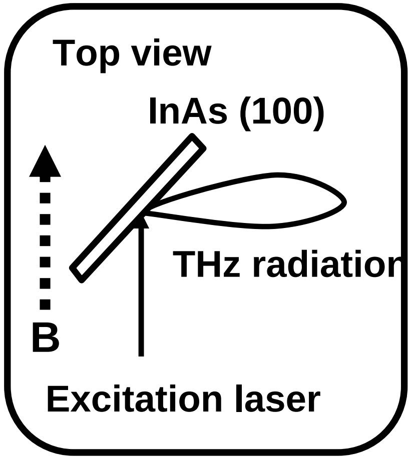
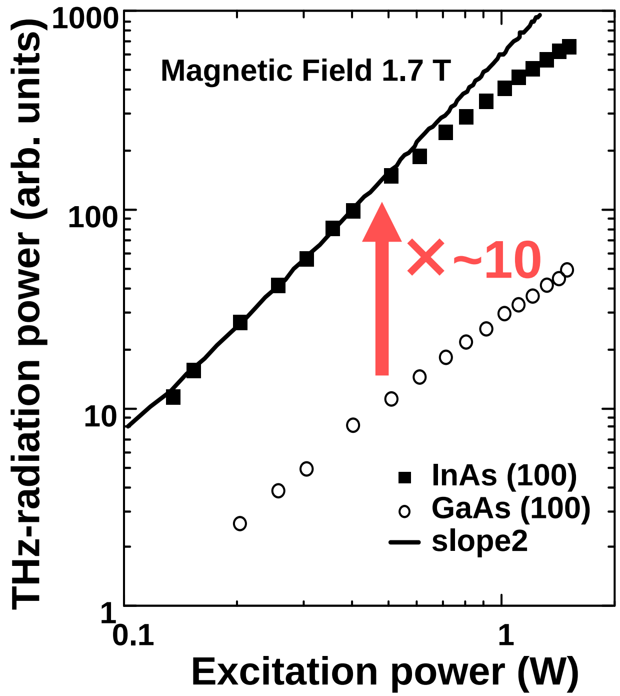
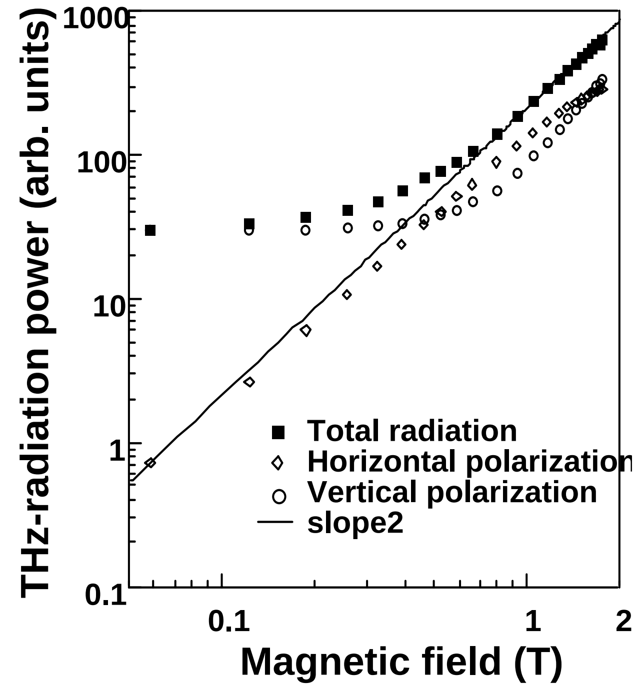
磁場中のInAsからのTHｚ電磁波放射







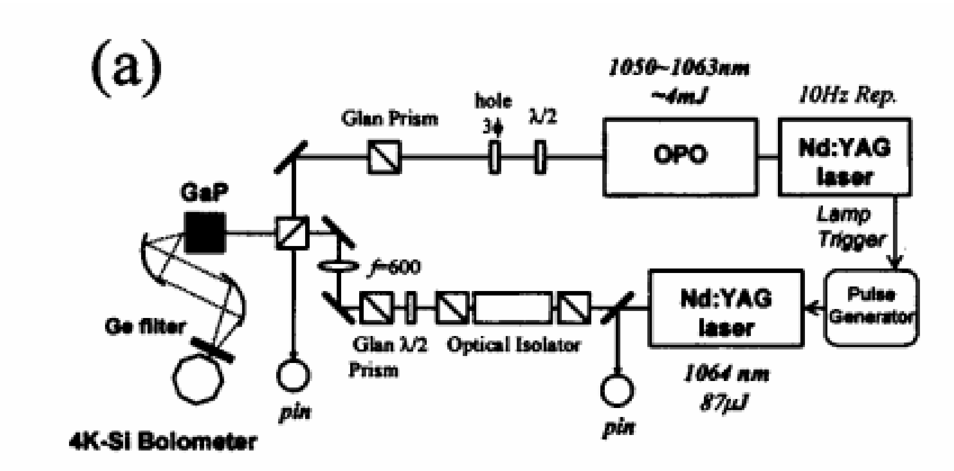
- InAsからのTHz電磁波はGaAsと比べ一桁ほど強い

  原因　(1/3 m_{eGaAs} ~ m_{eInAs})
- THz電磁波の強度は励起レーザーと磁場それぞれに２乗依存
- THz電磁波の変換効率　１０$^{-5}$～１０$^{-4}$

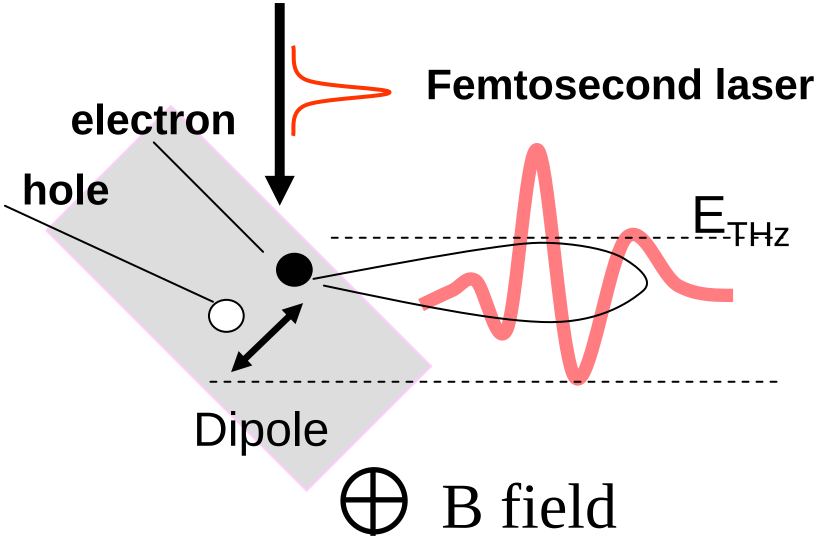
JAP 84, 654 (1998)

Future Plans

Combining these two THz generation designs…



J. Appl. Phys., Vol. 93, No. 8, 15 April 2003 Tanabe *et al.*



480 mW at 1.3 THz

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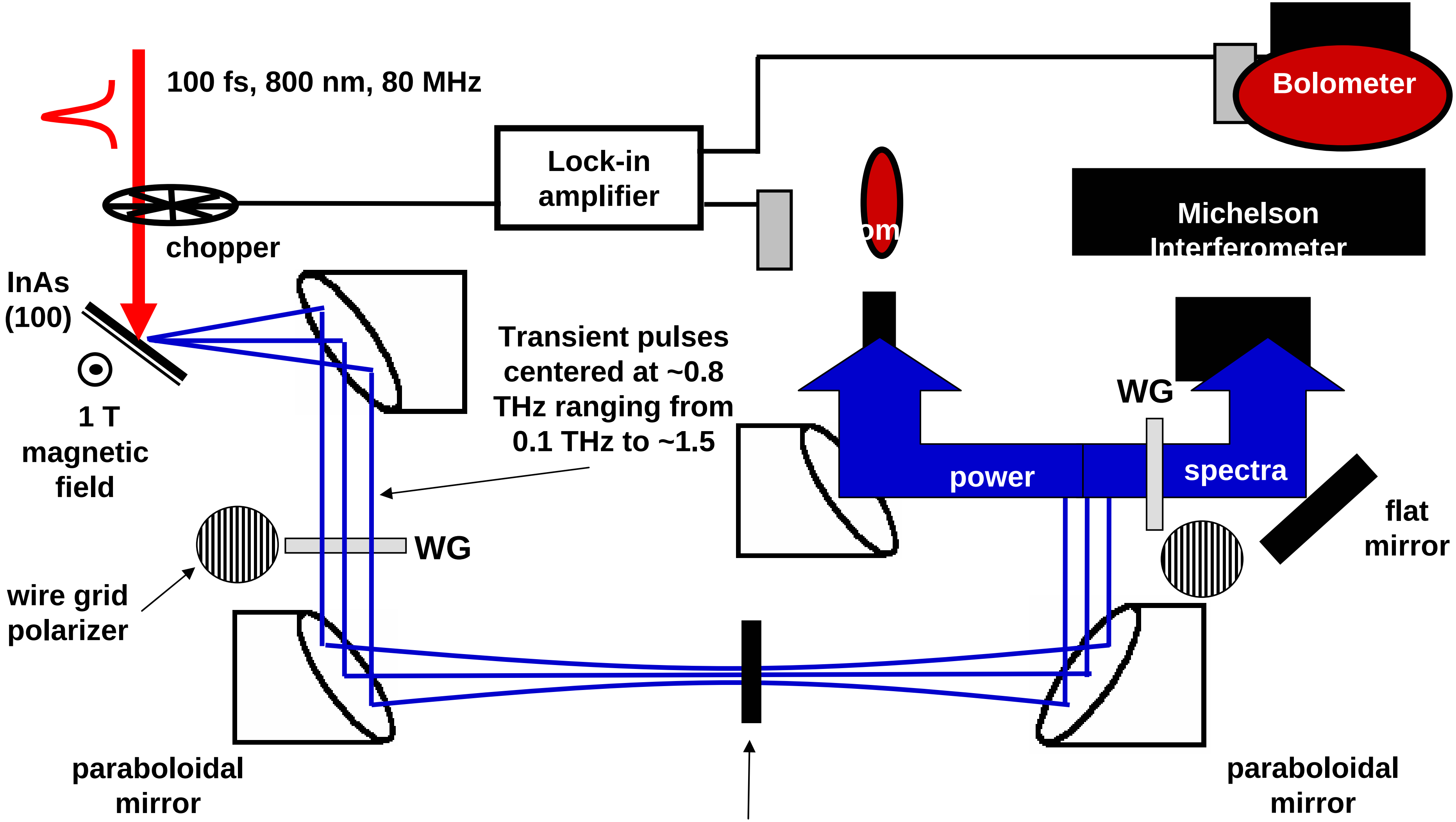
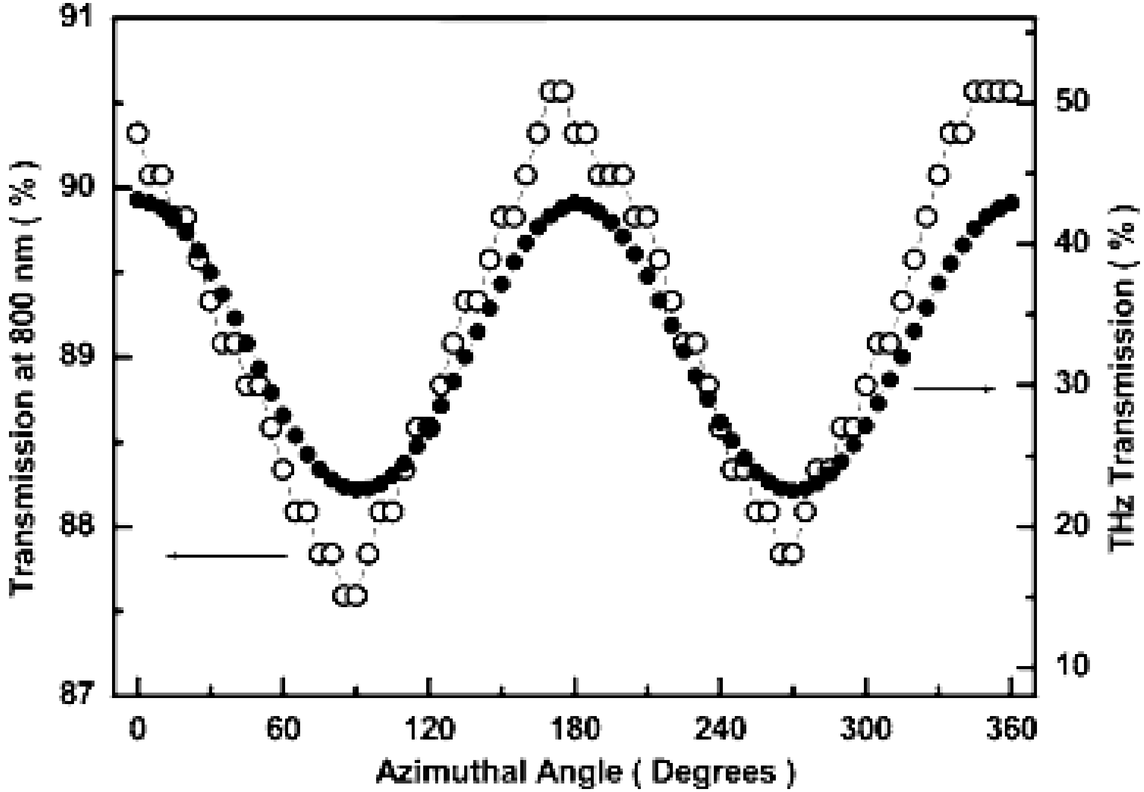
Experiment



Type I 10mm x 10 mm x 1 mm (thick) BBO crystal (Type I, $\theta=90^0$, $\Phi=90^0$, Crylight Photonics, Inc.) mounted on rotating holder

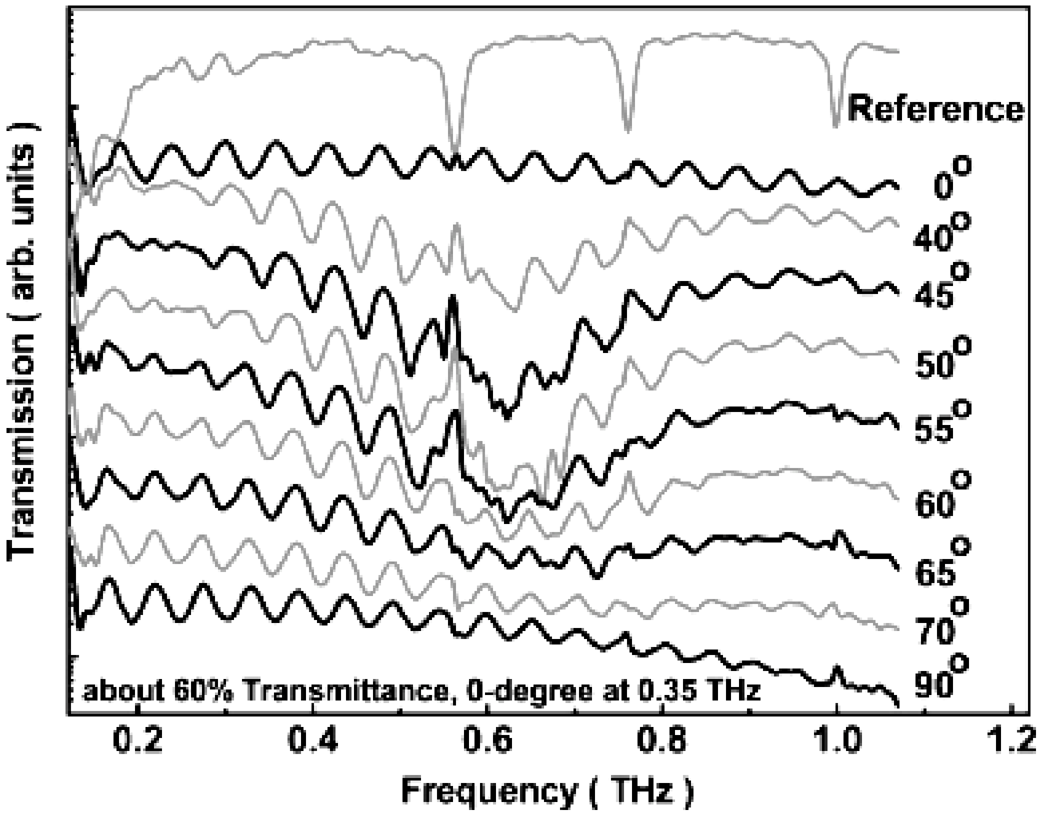
Results



$$R = \left[\frac{(n_2 - n_1)}{(n_2 + n_1)} \right]^2,$$

Azimuthal angle dependence of the 800 nm and broadband THz transmission of the BBO crystal, showing birefringence. The 0^0 orientation coincides with the crystal's c-axis.

Results



$$n = \frac{c}{2d(\nu_2 - \nu_1)\cos\theta},$$

Terahertz transmission spectra for selected azimuthal angle orientations. A strong absorption band at 0.65 THz for the 40º to 60º orientations is attributed to low frequency phonon modes of the $[B_3O_6]^{3-}$ rings. The BBO crystal exhibits 60% transmittance at 0.35 THz. We surmise, this is better than what was experimentally observed for $LiNBO_3$.

Results

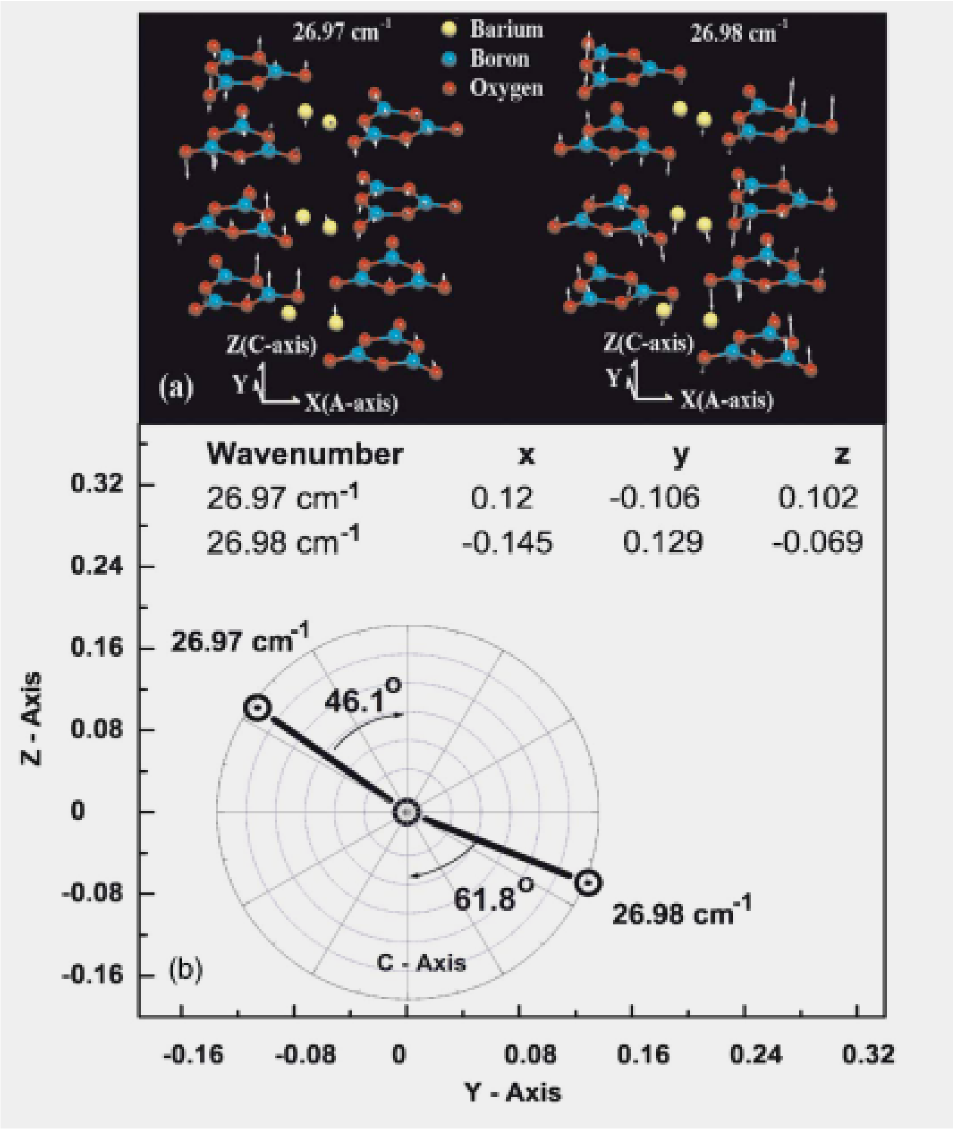
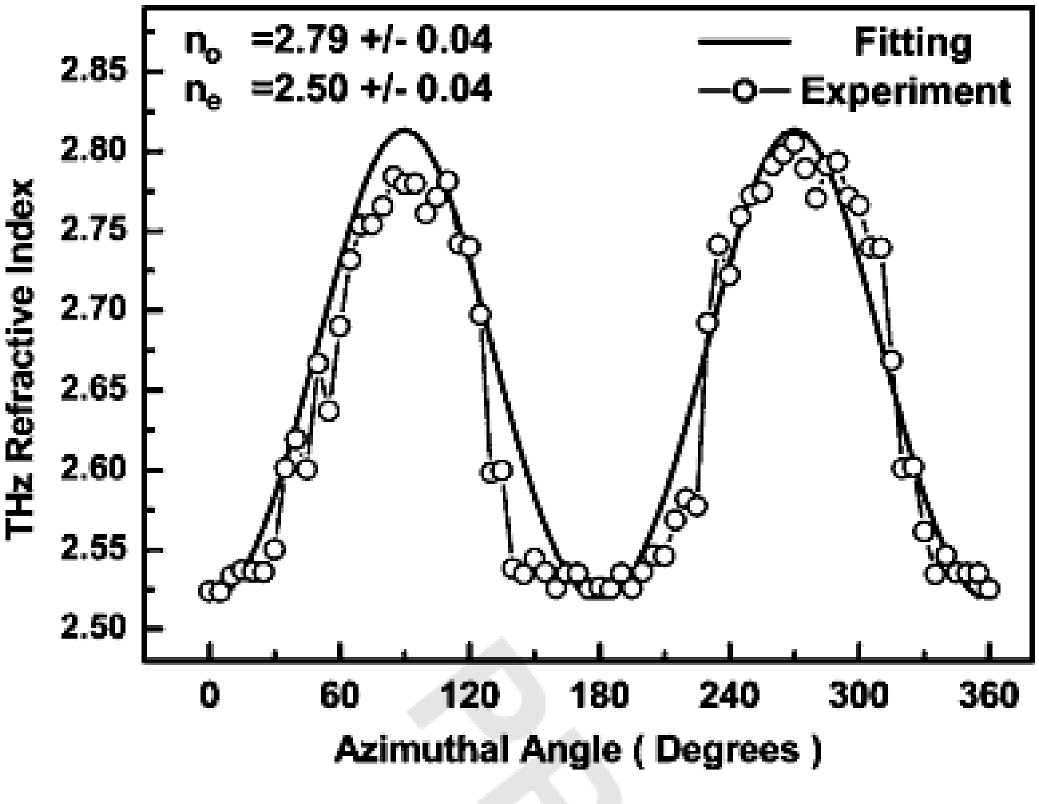
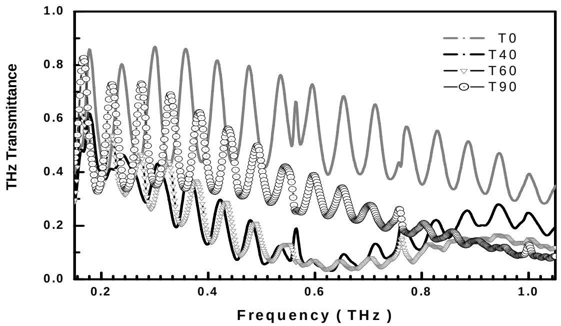


Illustration of the calculated phonon modes of the $[B_3O_6]^{3-}$ rings at ~27 cm^{-1}.

The projection of the calculated dipole moments to the y-z plane. The angular orientation of the dipole derivative projections with respect to the c-axis coincides with the orientation where the absorption at the 0.65 THz band was observed.

Results





$$\frac{1}{n_e(\theta)^2} = \frac{\sin^2(\theta)}{n_e^2} + \frac{\cos^2(\theta)}{n_o^2},$$

The angular dependence of the calculated refractive index values are shown in the open circle trace while the continuous line trace is a least squares fit.

$n_o \sim 2.79$

$n_e \sim 2.50$

Conclusions and Future Plans

We report experimental work on the optical properties of BBO in the 0.1 to 1.1 terahertz (THz) region. Primarily, results show that this material is significantly more transparent for submillimeter waves than $LiNBO_3$ and it was demonstrated that this material also exhibits birefringence in the THz range.

These findings could prove vital in utilizing phase matching conditions to realize BBO-based optical parametric devices operating the THz region.

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Birefringence of β-BaB_2O_4 crystal in the terahertz region for parametric device design

Elmer Estacio,[1,a)] Shigeki Saito,[1] Tomoharu Nakazato,[1] Yusuke Furukawa,[1] Nobuhiko Sarukura,[1] Marilou Cadatal,[2] Minh Hong Pham,[2] Carlito Ponseca, Jr.,[2] Hiroshi Mizuseki,[3] and Yoshiyuki Kawazoe[3]
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(Received 28 December 2007; accepted 11 February 2008)

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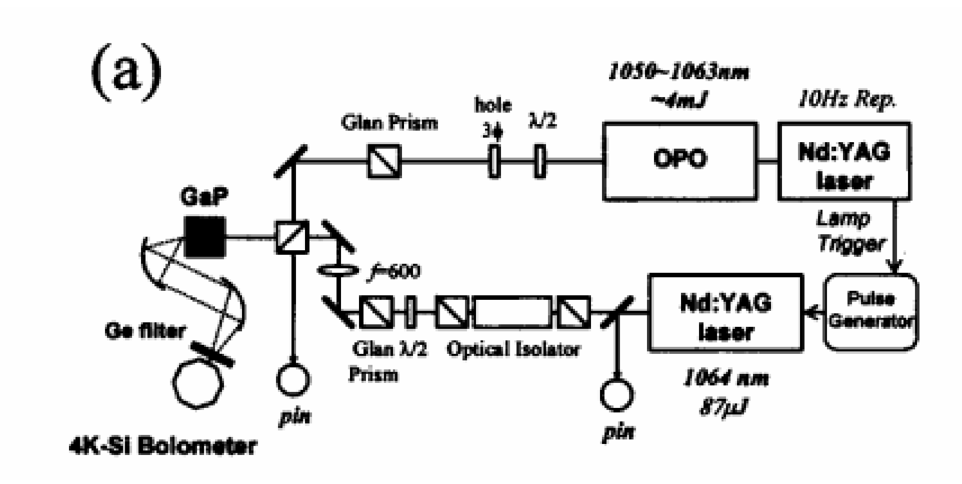

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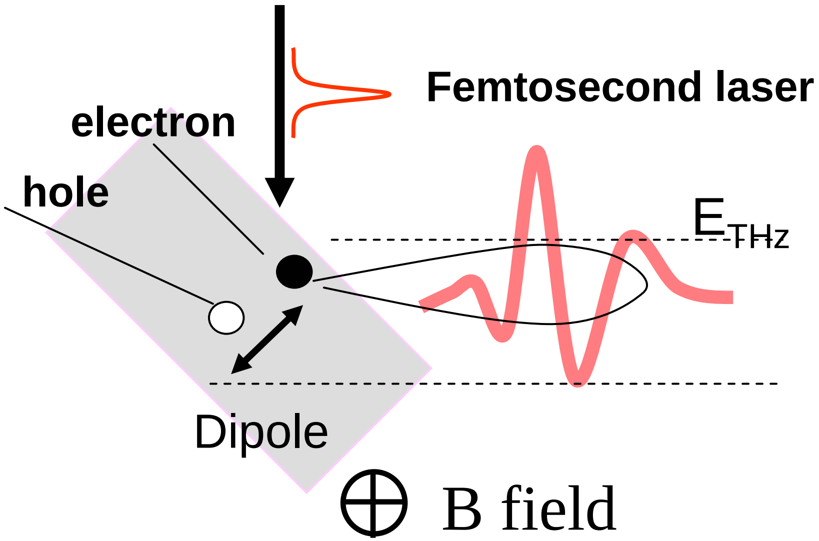

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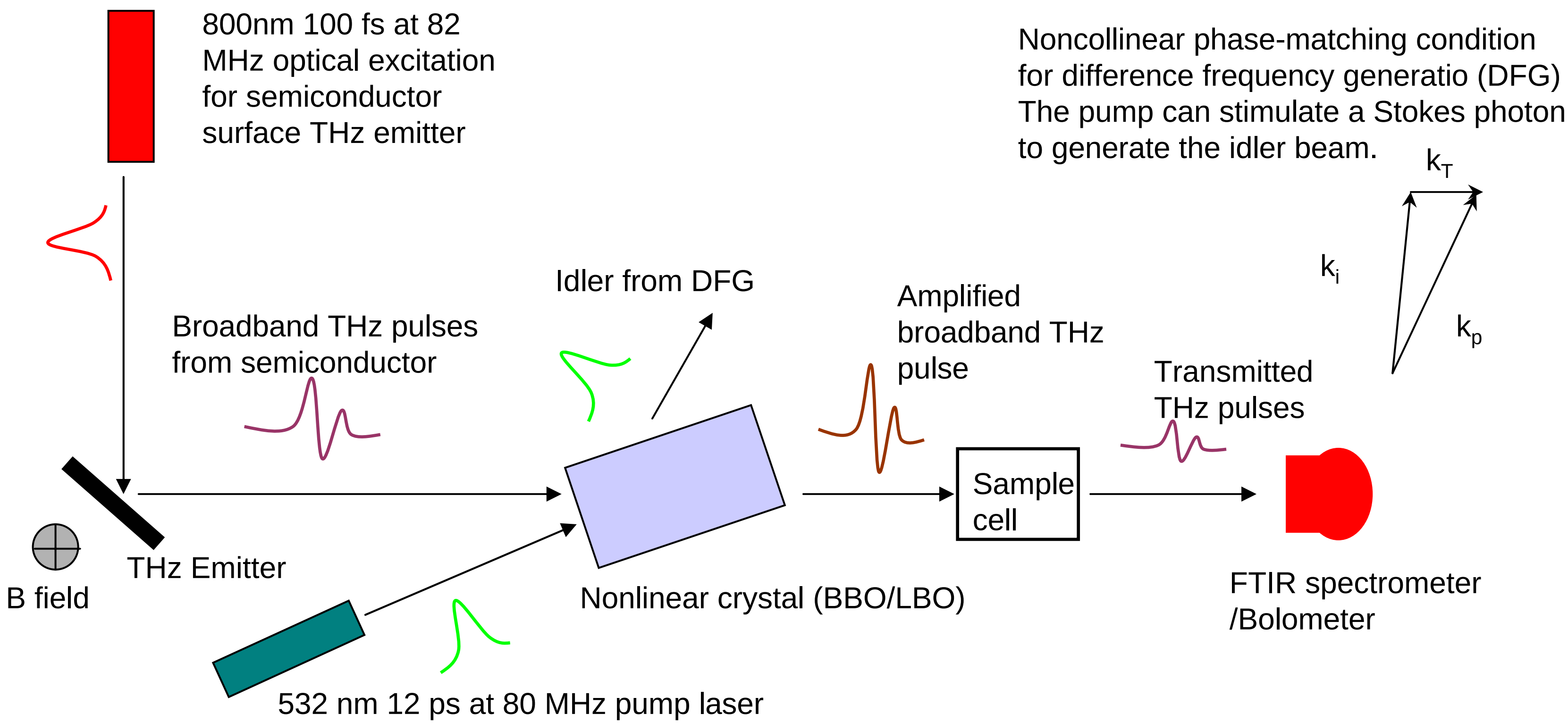
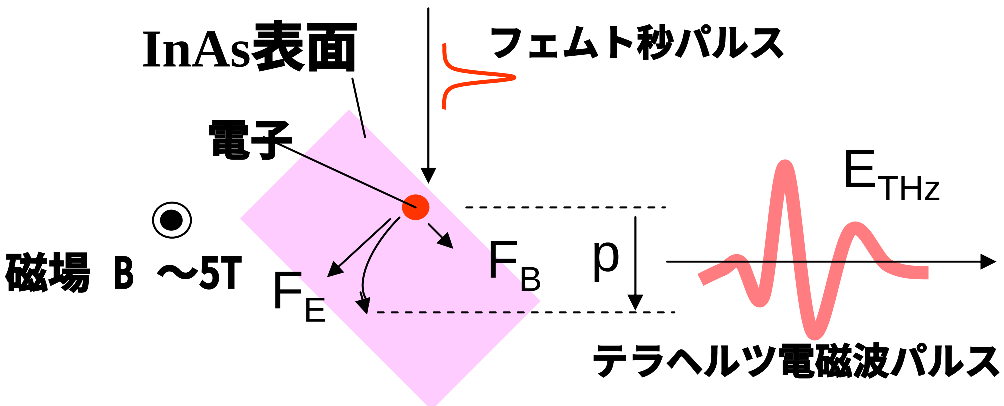
Future Plans

Design and development of a THz Optical Parametric Amplifier



半導体表面からのテラヘルツ電磁波発生と磁場による増強



キャリアの加速度

$$a(t) \propto \frac{\partial v}{\partial t} \propto \frac{\partial^2 p}{\partial t^2} \propto -\frac{e}{m_e}(E_{suf} + v \times B)$$

テラヘルツ電磁波強度

$$I_{THz} = E_{THz}^2 \propto \left(\frac{\partial \vec{J}}{\partial t}\right)^2 = (nea(t))^2$$

各種パラメーターへの依存性の調査
及び最適条件件の探索

⇩

高輝度光源の開発
増幅メカニズムの解明

- 半導体励起レーザー
  - 有効質量　出力
  - 表面状態　入射角度
  - 温度　偏光
  - パルス幅
  - チャープ量
- 磁場
  - 強度
  - 印加方向

磁場によるテラヘルツ電磁波発生の効率向上

Magnetic switching of THz beams

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L. E. Kingsley and M. Weiner
U.S. Army Research Laboratory, Pulse Power Center, Fort Monmouth, New Jersey 07703-5302

(Received 20 October 1992; accepted for publication 28 January 1993)

We demonstrate the use of a magnetic field to switch and to control the direction and polarization of a THz beam radiated from a semiconductor emitter.

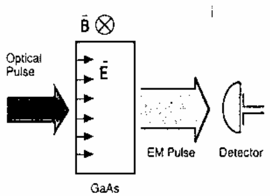

FIG. 1. The top view of the experimental configuration for the magnetic control of a THz beam.

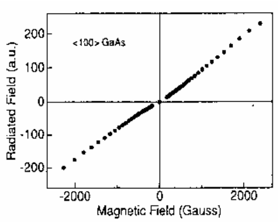

FIG. 3. The peak value of terahertz radiation vs the strength of the external magnetic field.

$$a = \frac{dv}{dt} = -\frac{e}{m_e^*}\left(E + v \times B\right)$$

@ Prof. X. -C. Zhang group

Rensselaer Rolytech. Inst.

APL. 62, 2003 (1993)

+　磁場に対する２乗依存性

- GaAsの重い有効質量
- ０.２　Tの低い磁場
- １００mW程度の低励起

磁場によるテラヘルツ電磁波発生の効率向上について、深入りをX．-C．Zhang はしなかった