



- (51) International Patent Classification:
G02F 1/35 (2006.01) *G02F 1/361* (2006.01)
- (21) International Application Number:
PCT/EP2014/060806
- (22) International Filing Date:
26 May 2014 (26.05.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
13169530.6 28 May 2013 (28.05.2013) EP
- (71) Applicant: **PAUL SCHERRER INSTITUT** [CH/CH];
CH-5232 Villigen PSI (CH).
- (72) Inventors: **HAURI, Christoph Peter**; Am Bach 8, CH-
5502 Hunzenschwil (CH). **RUCHERT, Clemens**;
Grendelstrasse 26, CH-5408 Ennetbaden (CH). **VICARIO,**
Carlo; Kellenäckerweg 5, CH-5303 Würenligen (CH).
- (74) Agent: **FISCHER, Michael**; Siemens AG, Postfach 22 16
34, 80506 München (DE).
- (81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM,
TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM,
ZW.

- (84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments (Rule 48.2(h))

(54) Title: TERAHERTZ LASER SYSTEM

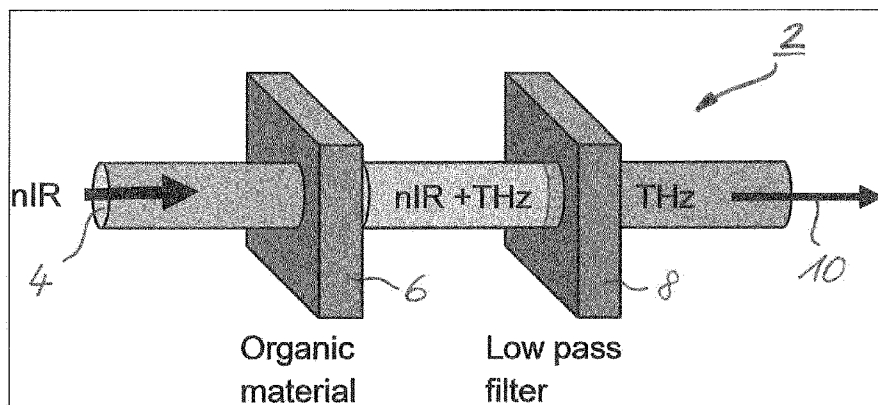


Fig. 1

(57) Abstract: It is the objective of the present invention to provide a Terahertz laser system. This objective is achieved according to the invention by a Terahertz laser apparatus, for example for use in skin cancer treatments, comprising: • a) a pump laser for generating a collimated near/mid-infrared pump laser pulse; • b) an organic crystal which receives the collimated near/mid-infrared pump laser pulse thereby generating Terahertz radiation by optical rectification in the nonlinear organic crystal; and • c) a low-pass filter for separating collimated near/mid-infrared pump laser pulse from the generated Terahertz radiation.

Terahertz laser system

The present invention relates to a Terahertz laser system that can be used for example in skin cancer treatment
5 applications.

It has been a challenge in the past to cover the Terahertz range between 1-20 Terahertz (so-called THz gap) with high-field (i.e. > MV/cm) and table-top Terahertz lasers. The
10 Terahertz frequency band lies between the optical frequencies (>20 THz) and the electronically accessible frequency range (<0.1 THz). In particular, the production of intense single-cycle and half-cycle pulses in this THz gap has been difficult to achieve. Such pulses require an ultra-
15 broadband spectrum of several octaves. Conventional techniques do not allow the formation of ultra-broadband spectra covering the THz gap and simultaneously delivering a high peak power. The most promising technique is based on a $\chi^{(2)}$ process, such as optical rectification (OR), or a $\chi^{(3)}$
20 process, such as difference frequency generation.

Very recently, high-power THz pulse generation was demonstrated by use of a LiNbO₃ crystal as THz emitter. However, this approach is limited to <3 THz and does not
25 cover the full THz gap. Furthermore, complicated pulse front tilting is required to achieve best phase-matching between the driving laser and the THz emission. Another drawback is that the generated THz beam is elliptical and has a different divergence in x and y. This makes it difficult to
30 achieve tight focusing and yet a real challenge to achieve high fields.

It is therefore the objective of the present invention to provide a Terahertz laser system that provides a Terahertz

radiation in the frequency of the so-called THz gap having high fields and a sufficient focusing of the radiation.

This objective is achieved according to the invention by a Terahertz laser apparatus, for example for use in skin cancer treatments, comprising:

- a) a pump laser for generating a collimated near/mid-infrared pump laser pulse, preferably delivering up to 20 mJ/cm²;
- b) an organic crystal which receives the collimated near/mid-infrared pump laser pulse thereby generating Terahertz radiation by optical rectification in the nonlinear organic crystal; and
- c) a low-pass filter for separating collimated near/mid-infrared pump laser pulse from the generated Terahertz radiation.

The generation scheme of the system is very simple. A femtosecond near/mid-infrared pump laser pulse is collimated and sent through an organic crystal. Terahertz radiation is produced by optical rectification in the nonlinear organic crystal. The pump laser is separated from the THz radiation by a low-pass filter. The THz output offers excellent characteristics for focusing. The THz divergence is the same in x and y, and the emitted THz offers a round, symmetric beam profile. Therefore, a diffraction-limited spot size can be achieved thanks to the excellent wave front properties. The use of an ultra-short pulse (i.e. <40 fs) allows the generation of pulses carrying a spectrum from 1 to 20 THz.

The present invention presents therefore a much easier and straight forward technique to generate intense and coherent THz radiation which offers excellent characteristics for tight focusing and high field production.

Organic crystals suitable for the generation of the Terahertz radiation are large-size phenolic configurationally locked polyene OH1 (2-(3-(4-hydroxystyryl)-5,5-dimethylcyclohex-2-enylidene)malononitrile) organic bulk crystals and ionic salts such as DAST (4'-dimethylamino-N-methyl-4-stilbazolium tosylate) and DSTMS (4-N,N-dimethylamino-4'-N'-methyl-stilbazolium 2,4,6-trimethylbenzene sulfonate) and other organic crystals like HMQ-TMS. Typically in these set-ups, the organic crystal can be chosen to have a clear aperture up to 12 mm at a nominal thickness of 0.5 mm. But larger sizes can be pumped by assembling different crystals to a mosaic-like structure. The nonlinear axis of the different crystals are then aligned parallel in order to achieve optical rectification in all crystals. This way crystal sizes as large as 30x30 mm², or larger can be achieved.

In a further preferred embodiment, the pump laser is a Cr:Fosterite laser system or a TW-class Ti:Sa laser. The Cr:Fosterite laser system is particularly suited to produce laser pulses being sufficiently collimated what is advantageous in case of various assembled crystals.

Furthermore, the use of an amplitude and phase shaper in the above mentioned pump laser systems is proposed to achieve a shaped output in the THz range between 1 to 20 THz. This allows the production of arbitrary shaped THz pulses.

The novel features in the solution according to the present invention are:

- a) The use of a high peak-power pump laser from a Cr:Fosterite, a Ti:Sa laser system or from an optical parametric amplifier with a collimated beam, short

pulse (<200 fs) in combination with a large size or mosaic-patterned organic crystal. This produces extremely high THz fields (>1 MV/cm) which cover the full THz gap.

- 5 b) The conversion technique offers collimated THz output with an excellent wave front and excellent beam profile. This allows to achieve focusing which is close to the diffraction limited spot size.
- 10 c) The large bandwidth and the high field open new opportunities. Examples for these opportunities are the cancer treatment, in particular skin cancer treatment, and a THz-based ultrafast x-ray switch. Other applications can be related to the exploration of fundamental physical phenomena and to biology and
- 15 homeland security.
- d) Terahertz pulse shaping across the THz gap via shaping of the pump beam allows the generation of almost arbitrarily shaped pulses.
- 20 The table below shows a summary of conventional techniques and their limitations and the last line of this table the properties achieved with the set-up according to the present invention.

Technique	Spectral output	Max. El. Field	Frequency range	Table-top?
THz Free electron laser	narrowband (<1%)	< 100 kV/cm	1-20 THz	No (few tens of meters)
Relativistic electrons	Broadband	70 MV/cm	5-20 THz	No (a few hundred meters)
Plasma-based approach	Octave	few 100 kV/cm	1-100 THz	Yes

LiNbO ₃ crystal	Octave	1 MV/cm	0.1-3 THz	Yes
Other crystals	Varia	<< MV/cm		Yes
Organic crystal	several octaves	Several MV/cm	0.1-20 THz	Yes

Table 1: Conventional techniques and THz generation with Organic Crystal according to the present invention.

For use in the above mentioned Terahertz cancer treatment,
 5 the inventive Terahertz source offers a novel approach for
 skin cancer treatment without affecting the surrounding
 healthy tissue. The idea behind is to irradiate the skin
 cancer cell with strong THz pulses, with a spectrum which
 matches the frequency "fingerprint" of the malign cells of
 10 the skin cancer. This allows deposition of laser pulse
 energy into THz-active modes of the malign cell leading to
 the destruction of the cell reproducibility. Terahertz
 pulses are a priori non-ionizing due to the low energy
 content of the individual photons. This makes them unique
 15 for skin cancer treatment.

So far, Terahertz has been used in medicine only for
 diagnostic purpose (imaging) since a powerful THz laser was
 not available. The commercially available THz lasers provide
 20 only low power and limited THz frequencies (<3 THz). So far,
 cancer treatment with THz was not considered and the
 properties of skin cancer cells in the 1-20 THz frequency
 range have not been explored in the past.

25 Another application for the high-peak power THz pulses is
 the realization of all-optical ultrafast magnetic switching.
 Terahertz allows a direct coupling of the magnetic field
 component to the magnetization. This allows to change the

direction of the magnetization coherently on an ultrafast timescale.

5 Other applications will cover highly nonlinear processes in gases and solids, such as the generation of high-order harmonics or the creation of novel meta-states in superconductors.

10 Preferred embodiments of the present invention are hereinafter described in more detail with reference to the attached drawings which depict in:

Figure 1 schematically a Terahertz radiation system;

15 Figure 2 schematically an experimental setup comprising a Terahertz radiation system according to Figure 1;

20 Figure 3 THz energy generated from 8 mm aperture DAST crystal as function of infrared pump energy and power density;

25 Figure 4 Focused THz generated in DSTMS together with vertical and horizontal projections and Gaussian fit;

Figure 5 Temporal (left) and spectral shapes (right) of the THz emitted by different organic crystals;

30 Figure 6 Direct manipulation of the absolute phase of the THz pulse by dispersion management by means of transparent plastic; and

Figure 7 Spectrum generated in 180 μm DAST crystal and reconstructed with first order autocorrelation.

Fig. 1 shows schematically a Terahertz radiation system 2 for the THz generation with a collimated pump laser 4, an organic crystal 6 emitting collimated THz radiation 10, which is separated by a low pass filter 8 from the pump laser pulses.

The experimental setup comprising the Terahertz radiation system 2 of Figure 1 is shown in Figure 2(a). Figure 2(b) shows a short pump pulse from an optical parametric amplifier that drives optical rectification in the organic crystal 6. Standard electro-optical sampling with a short 800 nm probe pulse is used for temporal and spectral characterization as illustrated in Figure 2(c).

In brief, a TW-class Ti:Sa laser 4 at 100 Hz, producing 60 fs FWHM pulses, drives an optical parametric amplifier (OPA) and provides at the same time a sub- μ J probe at 800 nm for electro-optical sampling (EOS). The OPA generates pulses with 70 fs FWHM duration and up to 2.5 mJ at the IR wavelengths required for THz generation in the organic crystals 6. Alternatively, a high-power Cr:Fosterite laser is used as it provides directly the wavelength required to pump the organic crystal. The THz is emitted from thin organic crystals 6 collinearly to the pump laser 4. Behind the organic crystal 6, a thin sheet of Teflon or blackened Topas polymer selectively blocks as the low pass filter 8 the residual IR laser pulses. The Terahertz beam 10 is expanded and then tightly focused by an off-axis parabolic (OAP) mirror ($f = 101.6\text{mm}$) for electro-optical sampling (EOS). The EOS gives direct access to the THz electric field shape, the peak electric field, and the spectral content. The electro-optical spectral sensitivity for this electro-

optical setup (GaP with 95 μm thickness) decreases above 5 THz with frequency cut-off at 7 THz.

5 The cut-off in the detection crystal is determined mainly by the group velocity mismatching between THz and optical probe and by the electro-optical spectral response. THz pulses with spectral components beyond 5 THz are measured by means of Fourier transform first order interferometry. It is realized in a Michelson interferometer equipped with Golay
10 cell detectors. The pellicle beam splitter installed in the interferometer is suitable for radiation in the frequency range from 0.7 to 20 THz. Absolute energy measurements are carried out by means of a calibrated Golay cell equipped with diamond entrance window (produced by Tydex) and of a
15 pyroelectric deuterated triglycine sulfate detector (DTGS model D201 manufactured by Bruker). The Golay cell sensitivity has been calibrated in energy up to 12 THz using a blackbody source. The transverse beam profile is recorded with a bolometer un-cooled camera having a pixel size of
20 23.5 μm .

In this disclosure, intense single-cycle THz transients generated in the organic crystals DAST, DSTMS, OH1 and HMQ-TMS are reported. In order to prevent crystal damage while
25 using the maximum available pump flux, large crystals with up to 12mm aperture at a nominal thickness of 0.5mm, and a mosaic-like crystal structure of 20x20 mm² have been utilized. On the other hand, thinner crystals are shown to be adequate for the generation of multi-octave spanning
30 spectra covering the entire THz gap.

In Figure 3, the THz pulse energy generated in a 0.5mm thick DAST crystal with an aperture of 8mm is shown as a function of the infrared laser energy and power density. The energy

stability of the THz pulse is comparable to the pump energy stability and equal to 1% rms. The temporal shape of the THz pulse is determined through EOS in a GaP crystal. The absolute THz energy is determined by the Golay cell

5 positioned after the low-pass filter and energy-calibrated THz attenuators. Maximum THz pulse energy $E_{\text{THz}} = 45 \mu\text{J}$ is reached when the crystal is pumped by $E_{\text{IR}} = 2.4 \text{ mJ}$ (at 160 GW/cm²). The experimental points confirm that the organic crystal 6 is operated far from the saturation. The pump-to-

10 THz energy conversion ($\eta_{\text{E}} = E_{\text{THz}}/E_{\text{IR}}$) is about 2%. This corresponds to a photon conversion efficiency η_{ph} larger than 200% ($\eta_{\text{ph}} = 100 N_{\text{THz}}/N_{\text{IR}}$, where N_{THz} and N_{IR} are the number of photons for the THz and the IR pump pulses).

15 Furthermore, the shot-to-shot THz energy stability is remarkable. The energy variation recorded over 500 consecutive shots is better than 1% rms comparable to the OPA energy stability (see error bars of Figure 3). The quasi-linear dependence of the generated energy indicates

20 that the upscale of the THz output by increasing the source energy is further feasible. It is worth noting that the maximum power density of 160 GW/cm² used is not inducing damages in the organic crystal. For other organic materials, the THz energy yield recorded in the same experimental

25 conditions is approximately 1%.

The THz generation occurs over several millimeters of crystal area illuminated by the pump. The THz beam therefore has a divergence of only a few mrad. In the present setup,

30 tight focusing is ensured by a 10 cm focal length parabola placed about 20cm from the THz organic crystal 6.

In Figure 4, the THz transverse intensity profile produced in an 8mm aperture DSTMS crystal is shown. The beam,

recorded with a micro-bolometer camera, indicates vertical and horizontal FWHM of 350 and 366 μm . The profile was recorded with an un-cooled bolometer array sensor. The focus shape is circular and not affected by astigmatism or other visible aberrations. As shown in the projected profiles, the intensity is well fitted by a Gaussian with full width half maximum (FWHM) of 360 μm , which is close to the diffraction limit. The beam size measurement carried out for other organic crystals also resulted in excellent focusing characteristics. The foci are somewhat larger but still in the order of sub-mm.

The temporal shapes (left plots) and the spectral shapes (right plots) of the THz radiation for DAST, DSTMS, and OH1 are shown in Figure 5. the THz radiation emitted by different organic crystals. The radiation is generated in approximately same thickness crystals: 0.43, 0.4, and 0.49mm for DAST, OH1, and DSTMS, respectively. In all the case the optical rectification process is driven by IR pump at power densities up to 160 GW/cm^2 . High energy per pulse concentrated in one or two optical cycles and very tight focusing, reported before, allow for high THz field. The peak electric field is calibrated against the THz electro-optical effect and crosschecked with fluence and pulse duration measurement. The spectral intensity, right side plots in Figure 5, is calculated by Fourier transformation of the corresponding temporal evolution. For all the crystals, the THz transient approximates a single-cycle temporal oscillation with different grade of asymmetry. The maximum field recorded for DSTMS displays a peak of 1.5 MV/cm and magnetic field of 0.5 T for a single crystal and more than 6 MV/cm and 2 T for a mosaic-like crystal structure. Even larger fields up to 100 MV/cm and 33 T are achieved when pumped by a Cr:Fosterite laser delivering 30

mJ pulse energy. For OH1 and DAST organic crystals, the peak field is slightly less than 1 MV/cm when pumped by the same pump fluence. With respect to OH1 and DAST, the higher frequencies for DSTMS result in a tighter focus and shorter THz pulse and thus in higher peak field. The calculated spectra reveal the absorption properties and phonon resonances of each organic material. Due to these absorptions, the temporal transients exhibit oscillations after the main pulse.

The THz pulse generated by optical rectification is characterized by a stable absolute phase. This is an important feature for field-sensitive applications. Equally important, for exploring nonlinear dynamics, is the generation of the highest field at the interaction by proper control of the absolute phase of the single/few cycle THz pulses. In fact, for the highest asymmetry and zero absolute offset, the THz pulse could potentially act as a quasi-unipolar stimulus. An efficient method to directly control the absolute phase of a THz pulse by combining dispersion properties of different transparent plastics was recently demonstrated. Teflon and Topas polymer sheets with different thickness were used in order to vary the THz absolute phase and forming a fully asymmetric pulse, as shown in Figure 6. The direct manipulation of the absolute phase of the THz pulse by dispersion management by means of transparent plastic causes the asymmetry. The pulses are characterized by a carrier envelope phase offset of (a) $\pi/3$ rad, (b) $\pi/6$ rad, and (c) zero. The energy losses and the peak field reduction associated with such phase manipulation are negligible. To the best of the present inventors, the absolute phase control for THz pulses has not been demonstrated so far for such multi-octave spanning spectra.

Moreover, in the present setup, the THz field polarity can be easily inverted by 180° rotation of the organic crystal.

Both the phase velocity mismatch and the THz re-absorption define the optimal thickness of the organic crystal and therefore the THz spectral content. For the generation of high frequencies, thin crystals are necessary. In Figure 7, the broadband spectrum generated via optical rectification in 180 μm thick DAST and reconstructed with first order autocorrelation is presented. The generated spectrum is relatively flat and extends over the full THz gap. Several absorption peaks due to phonon resonances in the organic crystal 6 are visible. To avoid the decrease of sensitivity caused by the electro-optic detection (at frequencies higher than 5 THz), the spectra are reconstructed by Fourier interferometry. Moreover, for these measurements, the low pass Teflon filter, which is transparent to up to 5 THz, is replaced by blackened home-developed Topas polymer, which is characterized by low absorption in the entire THz gap. The measured spectra are impressively large and extend far beyond 10 THz.

With organic crystals it is possible to produce high fields in the whole THz gap (0.1–10 THz) and, furthermore, it seems feasible to extend the spectral region up to frequencies only accessible by optical difference frequency generation (>20 THz). OH1, DAST, and DSTMS organic crystals have been discussed here in view of their potential of high-field generation in the THz gap (0.1–10 THz). All crystals turned out to be highly efficient (up to 2% energy conversion yield) and broadband THz emitters when pumped by a mJ femtosecond infrared pulse. The generated THz radiation offers multi-octave spanning, single-cycle, and phase-stable pulses with up to 1.5 MV/cm electric and 0.5 T magnetic

field strength. The generation scheme based on a collimated
pumping geometry provides excellent THz focusing
characteristics. A new method to efficiently control the
absolute phase and the polarity of the THz field has been
5 disclosed here, too. Ultra-broadband THz spectra covering
the frequency range 1-10 THz have been realized by optical
rectification in a thin organic crystal. The THz source
presented here will be of benefit for field-sensitive
investigations to drive extreme nonlinear phenomena in gases
10 and solids with single-cycle, half-cycle or arbitrarily-
shaped transients.

Patent Claims

1. Terahertz laser apparatus (2), for example for use in skin cancer treatments, comprising:

- 5 a) a pump laser (4) for generating a collimated near/mid-infrared pump laser pulse;
b) an organic crystal (6) which receives the collimated near/mid-infrared pump laser pulse thereby generating collimated Terahertz radiation by optical rectification in
10 the nonlinear organic crystal (6); and
c) a low-pass filter (8) for separating collimated near/mid-infrared pump laser pulse from the generated Terahertz radiation (10).

- 15 2. The apparatus according to claim 1, wherein the pump laser (4) is a TW-class Ti:Sa laser (with/without OPA) or a Cr:Fosterite laser.

3. The apparatus according to claim 1 or 2, wherein the
20 organic crystal (6) is a DAST ((diethylamino) sulfur Trifluoride) or a DSTMS (4-N, N-dimethylamino-4'-N'-methylstilbazolium 2,4,6-trimethylbenzenesulfonate) or a OH1 (2-(3-(4-hydroxystyryl)-5,5-dimethylcyclohex-2-enylidene)malononitrile) crystal.

- 25 4. The apparatus according to claim 3, wherein the organic crystal (6) has an aperture up to 12 mm at a nominal thickness of 0.5 mm, or a mosaic-like patterned organic crystal of any size.

30

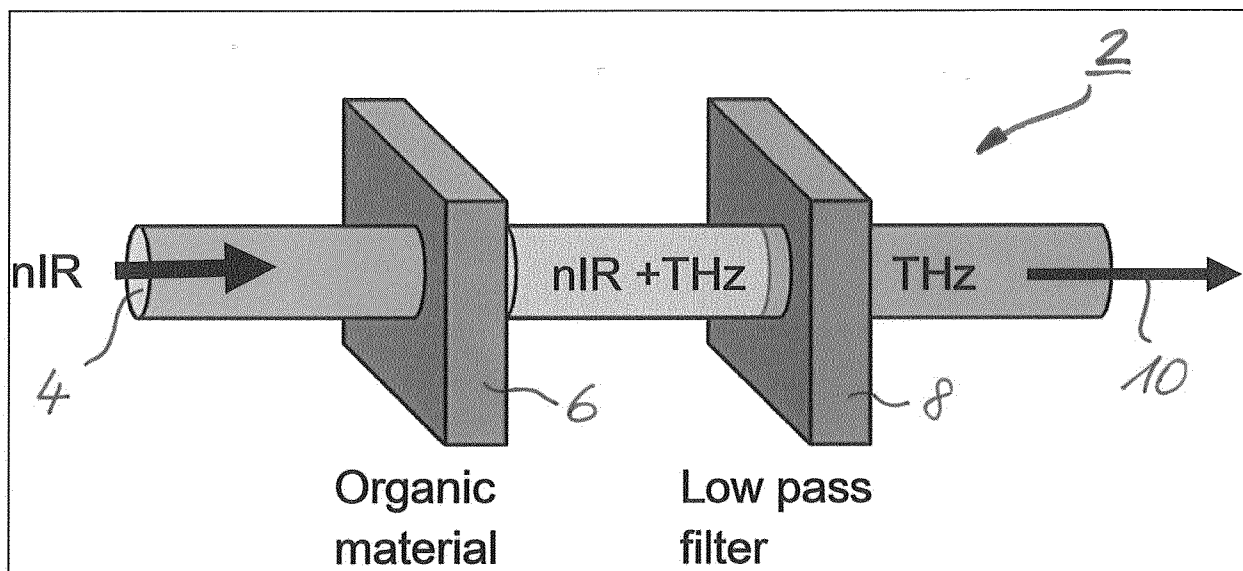
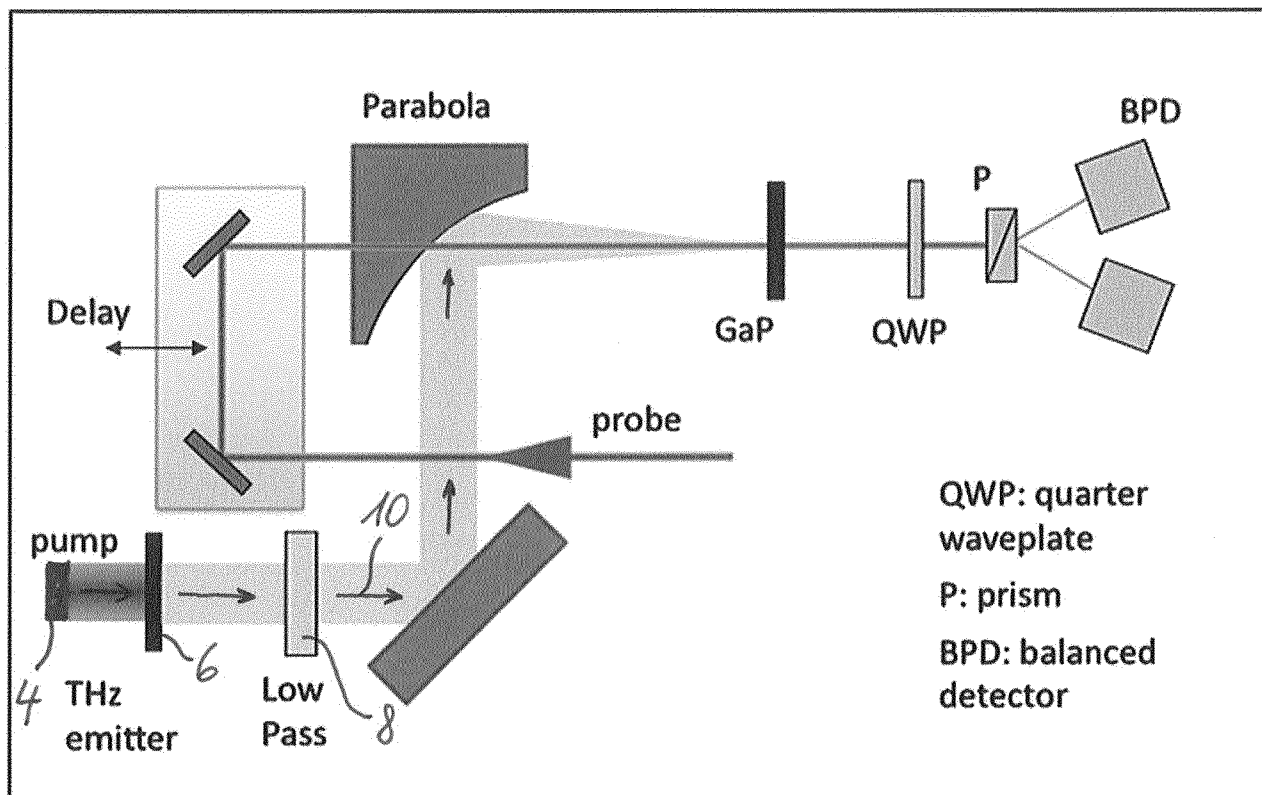


Fig. 1



(a)

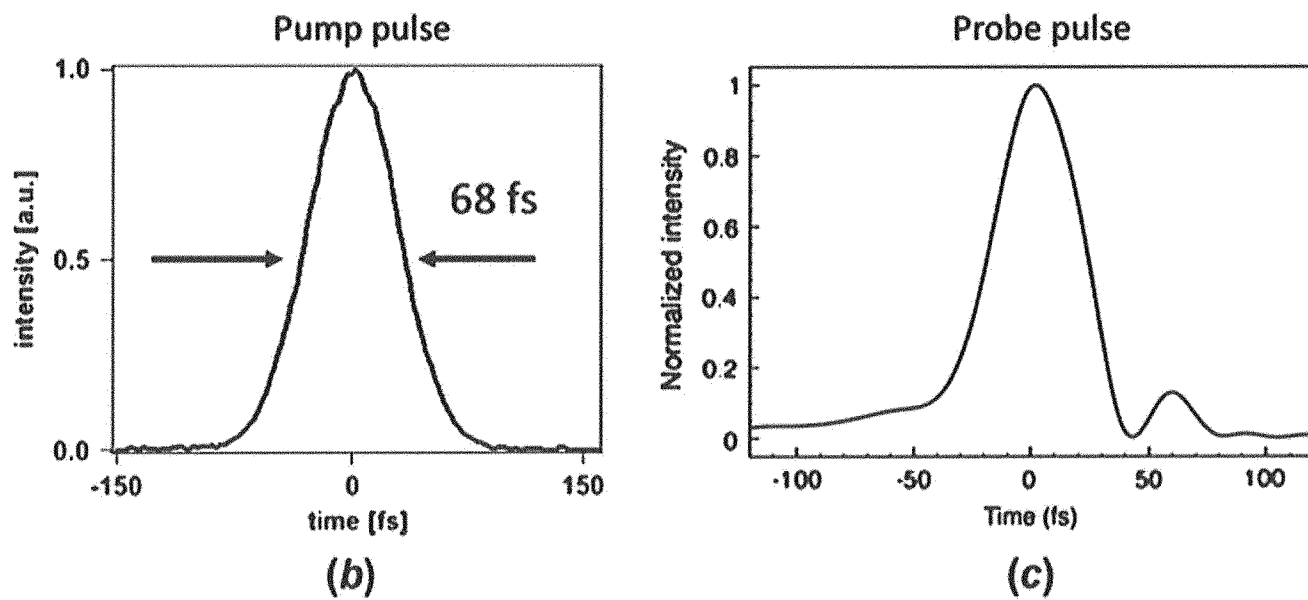


Fig. 2

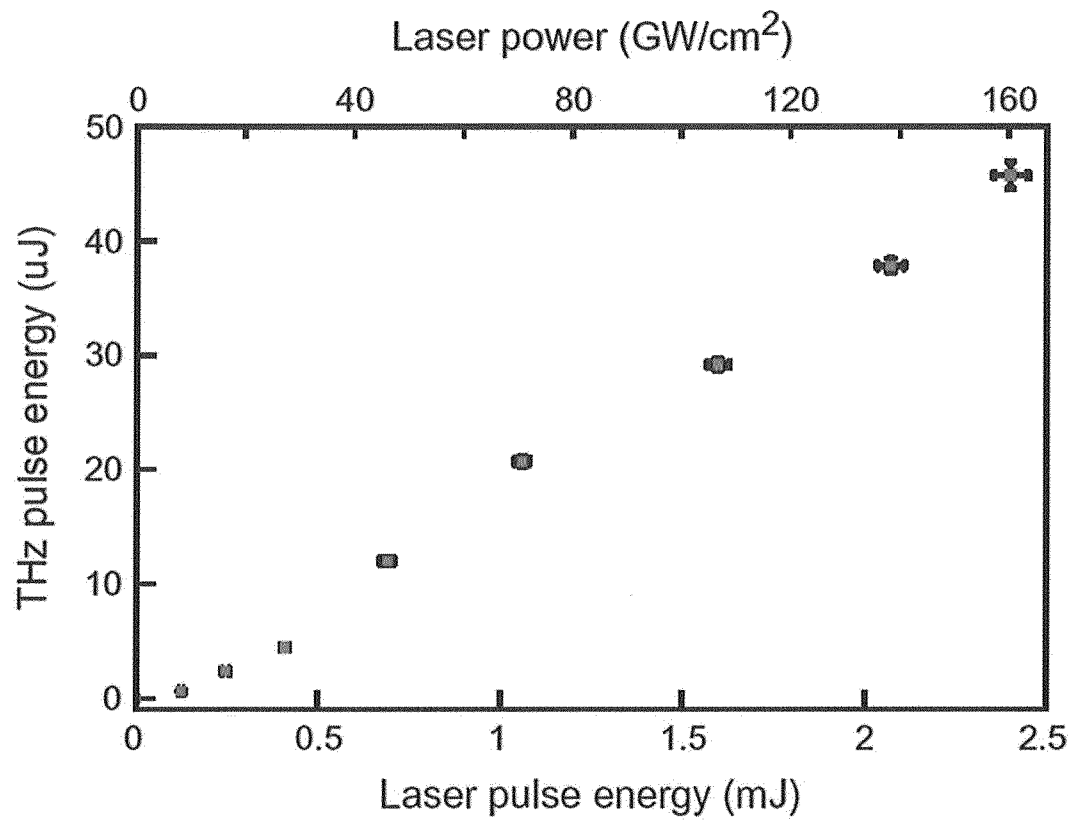


Fig. 3

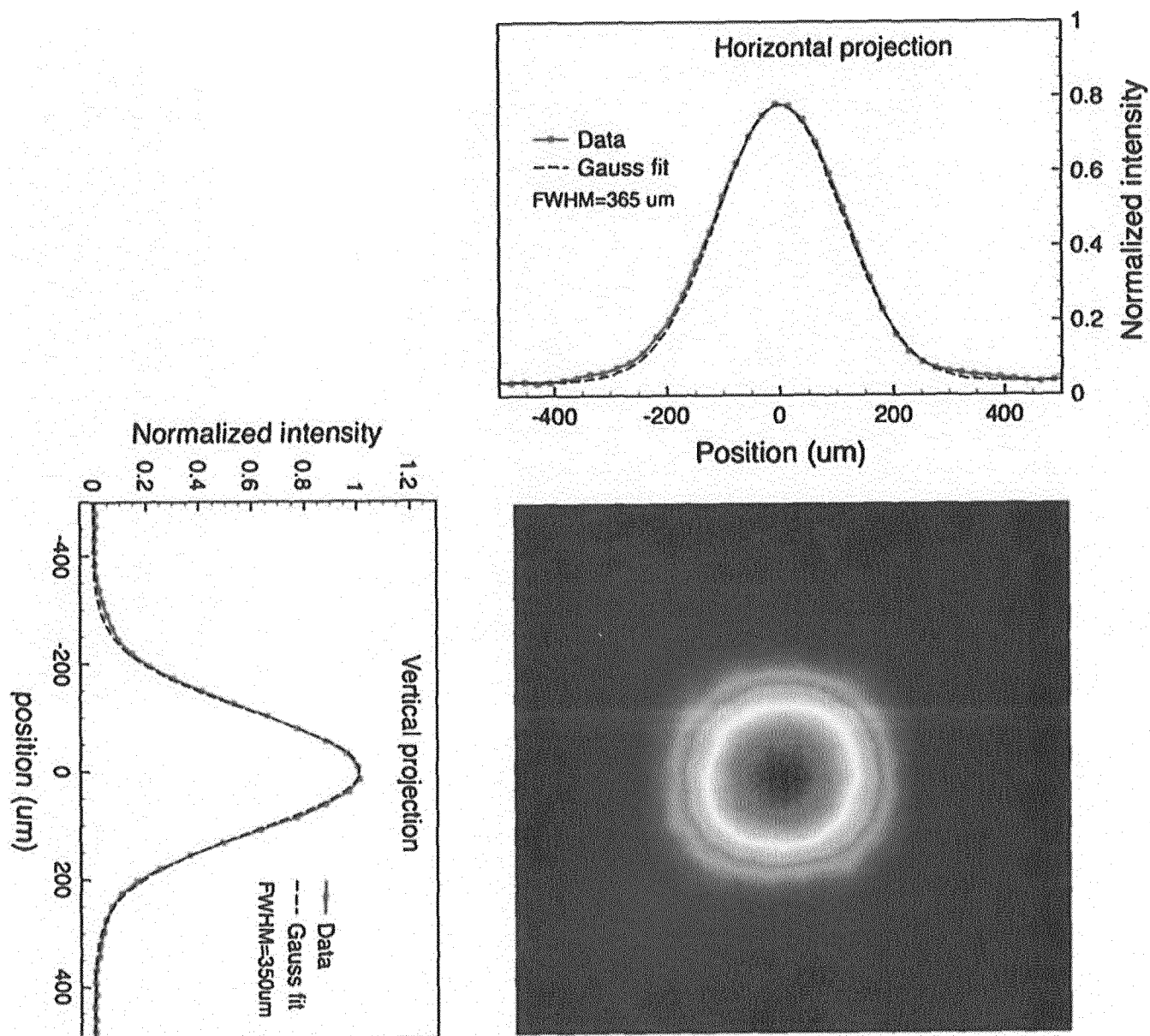


Fig. 4

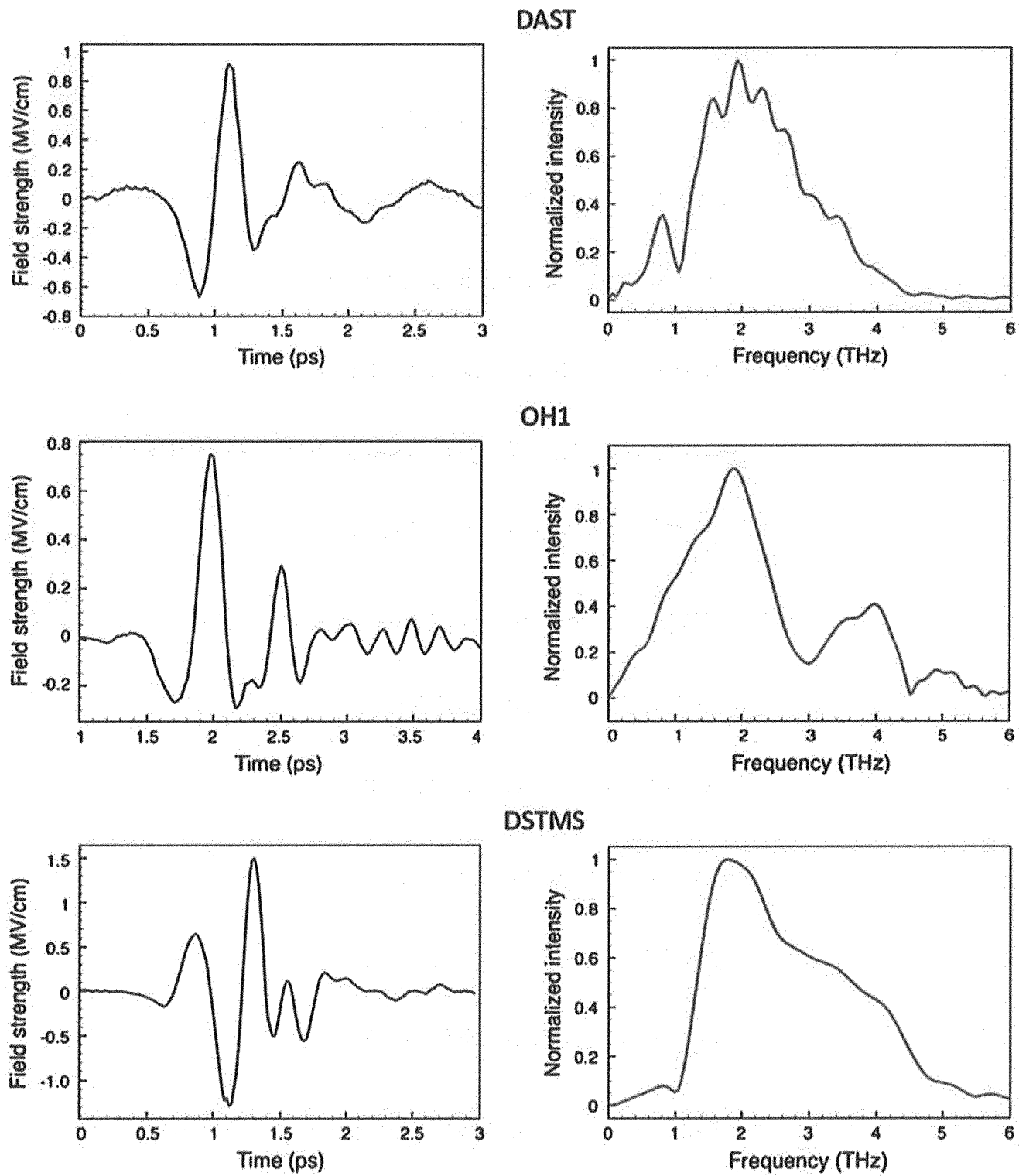


Fig. 5

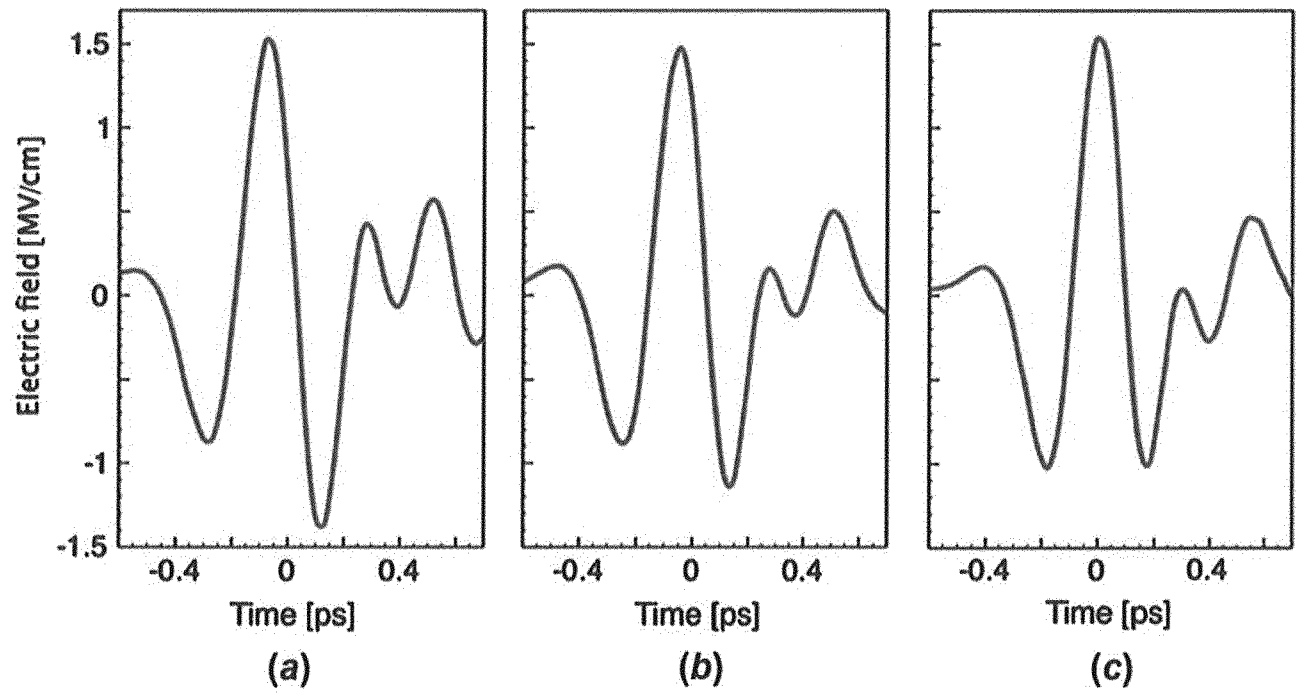


Fig. 6

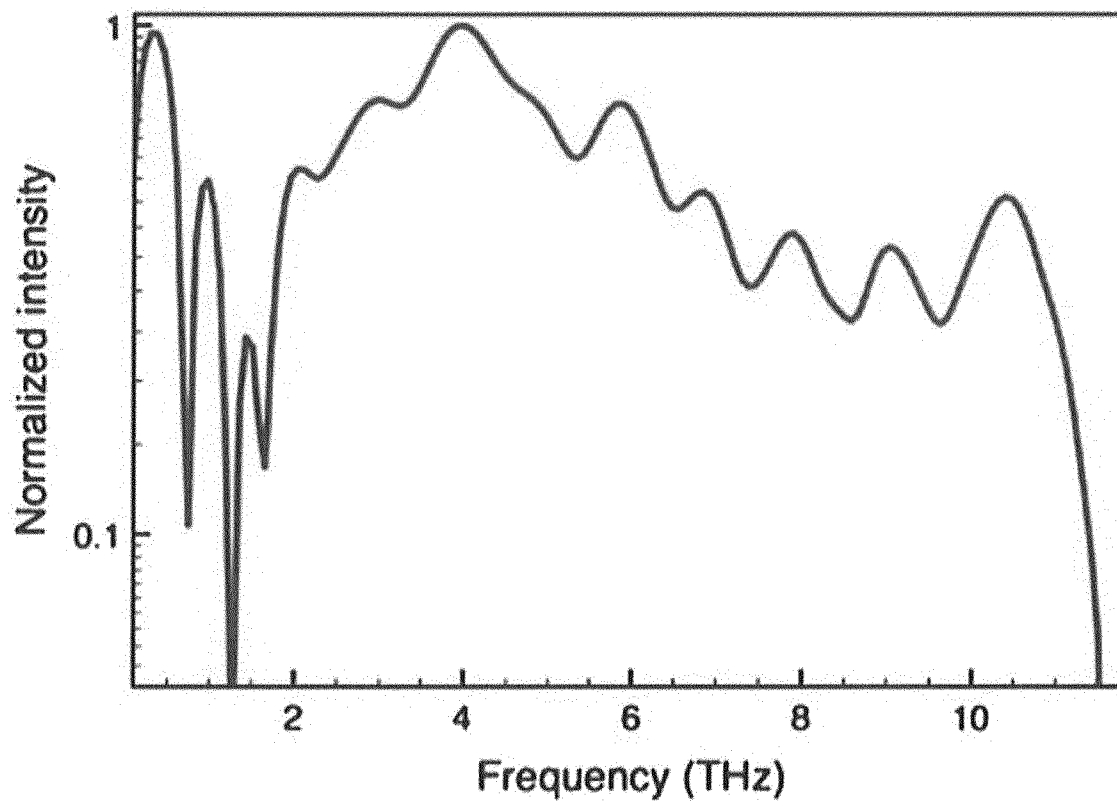


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/060806

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02F1/35 G02F1/361
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, COMPENDEX, INSPEC, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CLEMENS RUCHERT ET AL: "Scaling submillimeter single-cycle transients toward megavolts per centimeter field strength via optical rectification in the organic crystal OH1", OPTICS LETTERS, OPTICAL SOCIETY OF AMERICA, US, vol. 37, no. 5, 1 March 2012 (2012-03-01), pages 899-901, XP001574019, ISSN: 0146-9592, DOI: 10.1364/OL.37.000899 [retrieved on 2012-02-24]	1-4
Y	the whole document ----- -/-	2



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 September 2014

Date of mailing of the international search report

24/09/2014

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Stang, Ingo

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2014/060806

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	C. VICARIO ET AL: "Intense THz radiation produced in organic salt crystals for high-field applications", PROCEEDINGS OF SPIE, vol. 8604, 12 March 2013 (2013-03-12), page 86040C, XP055139324, ISSN: 0277-786X, DOI: 10.1117/12.2010871 the whole document	1-4
X	----- US 2009/303574 A1 (GUNTER PETER [CH] ET AL) 10 December 2009 (2009-12-10) paragraphs [0059], [0071] - [0073], [0081]; figure 4	1-3
Y	----- GB 2 347 756 A (TOSHIBA RES EUROP LTD [GB]) 13 September 2000 (2000-09-13) page 14, line 15 - line 17; claims 1,4,6,7,8	2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2014/060806

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009303574 A1	10-12-2009	EP 2013948 A1	14-01-2009
		US 2009303574 A1	10-12-2009
		WO 2007121598 A1	01-11-2007

GB 2347756 A	13-09-2000	GB 2343964 A	24-05-2000
		GB 2347756 A	13-09-2000
		JP 2000162656 A	16-06-2000
