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SEARCH REPORT

Application Number
LH 24
LT 2020559

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	WEI KAIHUA ET AL: "Fiber laser pumped high power mid-infrared laser with picosecond pulse bunch output", OPTICS EXPRESS, vol. 21, no. 21, 17 October 2013 (2013-10-17), page 25364, XP055828394, DOI: 10.1364/OE.21.025364 Retrieved from the Internet: URL:https://www.osapublishing.org/DirectPDFAccess/0D491510-CDB9-411B-A155B51545FB2838_269800/oe-21-21-25364.pdf?da=1&id=269800&seq=0&mobile=no> * page 25366; figure 1 * * page 25368, paragraph 2 - page 25372, paragraph 3; figures 4,6,9 *	1-17	INV. H01S3/23 G02F1/39 ADD. H01S3/00 H01S3/11
A,D	WU YUDI ET AL: "Compact picosecond mid-IR PPLN OPO with controllable peak powers", OSA CONTINUUM, vol. 3, no. 10, 22 September 2020 (2020-09-22), page 2741, XP055828473, DOI: 10.1364/OSAC.400213 Retrieved from the Internet: URL:https://www.osapublishing.org/DirectPDFAccess/AE31301E-084C-4735-AFE7CE7A4D53DB84_439892/osac-3-10-2741.pdf?da=1&id=439892&seq=0&mobile=no> * page 2742, paragraph 2 - page 2745, paragraph 1; figures 1-3,5 *	1-17	
A	US 2020/067260 A1 (BARKAUSKAS MARTYNAS [LT] ET AL) 27 February 2020 (2020-02-27) * paragraphs [0025] - [0038] *	1-3,16	

-/--

TECHNICAL FIELDS SEARCHED (IPC)
H01S
G02F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	29 July 2021	Riechel, Stefan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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EPO FORM 1503 11.08 (P04C80)

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A,D	HE LI-JIAO ET AL: "305-[mu]J, 10-kHz, picosecond optical parametric oscillator pumped synchronously and intracavity by a regenerative amplifier", OPTICS LETTERS, vol. 43, no. 3, 29 January 2018 (2018-01-29), page 539, XP055828363, US ISSN: 0146-9592, DOI: 10.1364/OL.43.000539 Retrieved from the Internet: URL:https://www.osapublishing.org/DirectPDFAccess/F30A9516-FB66-4469-8AA81E601B5180B7_381127/ol-43-3-539.pdf?da=1&id=381127&seq=0&mobile=no> * page 540, left-hand column, paragraph 3 - page 542, left-hand column, paragraph 1; figures 1,4 * -----	1,16	
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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1

EPO FORM 1503 11.08 (P04C80)

ANNEX TO THE SEARCH REPORT ON LITHUANIAN PATENT APPLICATION NO.

LH 24
LT 2020559

This annex lists the patent family members relating to the patent documents cited in the above-mentioned search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-07-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2020067260 A1	27-02-2020	CN 110582904 A	17-12-2019
		EP 3622594 A1	18-03-2020
		GB 2562236 A	14-11-2018
		KR 20200004848 A	14-01-2020
		US 2020067260 A1	27-02-2020
		WO 2018207042 A1	15-11-2018

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WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
LH24	02.12.2020		LT2020559

International Patent Classification (IPC)
INV. H01S3/23 G02F1/39 ADD. H01S3/00 H01S3/11

Applicant
UAB "EKSPLA"

This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of the opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the application
- ☒ Box No. VIII Certain observations on the application

	Examiner
	Riechel, Stefan

Application number

WRITTEN OPINION

LT2020559

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-17
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-17
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-17
	No:	Claims	

2. Citations and explanations

see separate sheet

Application number

WRITTEN OPINION

LT2020559

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1 WEI KAIHUA ET AL: "Fiber laser pumped high power mid-infrared laser with picosecond pulse bunch output",OPTICS EXPRESS, vol. 21, no. 21, 17 October 2013 (2013-10-17), page 25364, XP055828394

D2 WU YUDI ET AL: "Compact picosecond mid-IR PPLN OPO with controllable peak powers", OSA CONTINUUM, vol. 3, no. 10, 22 September 2020 (2020-09-22), page 2741, XP055828473

D3 US 2020/067260 A1 (BARKAUSKAS MARTYNAS [LT] ET AL) 27 February 2020 (2020-02-27)

D4 HE LI-JIAO ET AL: "305-[mu]J, 10-kHz, picosecond optical parametric oscillator pumped synchronously and intracavity by a regenerative amplifier", OPTICS LETTERS, vol. 43, no. 3, 29 January 2018 (2018-01-29), page 539, XP055828363

1 Novelty

1.1 D1 discloses (page 25366; figure 1; page 25368, paragraph 2 - page 25372, paragraph 3; figures 4,6,9) a mid-infrared source of pulsed laser radiation comprising a pump pulse source (Figure 1) and an optical parametric oscillator (Figure 6),
wherein said pump pulse source comprises (Fig 1; page 25366, second paragraph):
- a laser oscillator (Figure 1: mode locked fiber laser and spectrum purifier) generating a continuous train of picosecond seed pulses (50ps duration after the FBG), defined by a first repetition rate f1 in the range from 10 kHz to 100 MHz (2.72 MHz repetition rate);
- a module for pulse bursts formation and amplification (Figure 1: pulse multiplier and amplifiers) which provides (see page 25368, paragraphs 2 - 4; Figure 4) a sequence of bursts of pump pulses, wherein each said burst of pump pulses consists of picosecond (see Figure 4) pump pulses repeating at a second repetition rate f2 which is higher than said first repetition rate and is in the range from 200 MHz to 2 GHz (interval of 1.26 ns corresponding to ~800MHz); a time interval between adjacent bursts of pump pulses corresponds to a third repetition rate f3 which is lower than the second repetition rate f2 and equal to the first repetition rate f1;
said optical parametric oscillator comprises (see Figure 6):

- at least one optical parametric amplification nonlinear crystal (PPMgLN), placed inside an optical resonator (M1, M2), wherein two photons of lower energy are generated from one photon of radiation of pump wavelength: a signal wave photon and an idler wave photon (page 25370, first paragraph);
- at least two mirrors (M1, M2) which form said optical resonator of a length L2,

the pump pulse source and the optical parametric oscillator are mutually matched so that a roundtrip time of the resonator of the optical parametric oscillator is equal to a time interval 1/f2 between adjacent pump pulses (page 25370, first paragraph);
the optical parametric oscillator provides a sequence of bursts of output pulses (Figure 9), wherein each said burst of output pulses consists of picosecond pulses (abstract; Figure 9) of signal and/or idler wave (Figure 9: signal).
The output wavelength is tunable e.g. over the signal and idler bands (page 25370, first paragraphs), e.g. by adjusting the OPO resonator length (page 25370, first paragraphs) so that the wavelength changes for which the synchronous pumping condition is fulfilled best or by changing the pump power (see e.g.Figure 8).

The subject-matter of claim 1 therefore differs from this known wavelength tunable source by the features listed in the characterising portion, in particular in that
the module for pulse burst formation and amplification comprises a solid state regenerative amplifier having one or two optical switches inside its resonator; wherein
said optical switches are configured so that, by applying a voltage to both or one of the optical switches, seed pulses spaced apart by a time interval 1/f3, are trapped inside the resonator; by turning off of the voltage on one of the optical switches or reducing the voltage on both or one of the optical switches at a time moment f1, a partial transmittance of the resonator is created for a time interval Δt which is longer than a roundtrip time of the resonator, and a part of energy of a pulse circulating inside the resonator is coupled out;
wherein each burst of pump pulses contains from 7 to 15 consecutive pump pulses with a peak power exceeding 800 kW, while a sum energy of each burst of pump pulses is not less than 300 μJ.

1.2 D2 discloses (page 2742, paragraph 2 - page 2745, paragraph 1; figures 1-3,5) a mid-IR OPO that is synchronously pumped by bursts of ps pulses generated by laser diode gains switched at a 1.5 GHz repetition rate which is externally modulated to form a 1 MHz inter burst repetition rate. The subject-matter of claim 1 differs therefrom at least by a module for burst formation and amplification comprising a solid state regenerative amplifier.

1.3 D3 discloses (paragraphs [0025] - [0038]) alternative configurations of regenerative amplifiers for generating burst of pulses with a repetition rate higher than the repetition rate of the seed pulse source.

1.4 D4 does not disclose an OPO synchronously pumped by the output of the regenerative amplifier.D4 discloses (page 540, left-hand column, paragraph 3 - page 542, left-hand column, paragraph 1; figures 1,4) a picosecond optical parametric oscillator pumped synchronously by a regenerative amplifier. The non-linear crystal of the OPO is provided within the resonator of the regenerative amplifier, so that the pump pulses are not coupled out of the regenerative amplifier. A single pulse is coupled out of the OPO by providing a switch for cavity dumping. Hence, the subject-matter of claim 1 differs from D4 at least in that the optical switches are configured so that, by turning off of the voltage on one of the optical switches or reducing the voltage on both or one of the optical switches at a time moment f1, a partial transmittance of the resonator is created for a time interval Δt which is longer than a roundtrip time of the resonator, and a part of energy of a pulse circulating inside the resonator is coupled out;
wherein each burst of pump pulses contains from 7 to 15 consecutive pump pulses with a peak power exceeding 800 kW, while a sum energy of each burst of pump pulses is not less than 300 μJ; and
the optical parametric oscillator provides a sequence of bursts of output pulses, wherein each said burst of output pulses consists of picosecond pulses, and each burst of output pulses has from 5 to 10 consecutive output pulses with a peak power exceeding 10 kW in the entire wavelength tuning range.

1.5 The subject-matter of independent claim 1 is therefore new with respect to the cited prior art.

2 Inventive step

2.1 D1is regarded as being the prior art closest to the subject-matter of claim 1. The problem to be solved by the present invention may be regarded as providing output pulse bursts with higher energy.

2.2 The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step for the following reasons:
D1 mentions two factors that limit the idler output power, namely back-conversion due to high reflection of the mirror M2 for the signal (page 25370, last paragraph) and a limited efficiency due to inaccurate sub-pulse intervals (page 25372, second paragraph). D1 suggests to improve the OPO efficiency through better synchronisation (page 25372, "conclusions"). D1 therefore prompts a person skilled in the art facing the objective technical problem to a provide a more accurate repetition rate multiplier. At least one solution to this problem is known, see Barulevicius et al cited on page 2, second paragraph. D1 therefore prompts away from the solution of claim 1.

If the skilled person nevertheless considers to replace the high repetition rate pulse source of D1 by an pulse source of different construction, then various alternatives are known in the art which have been used for synchronously pumping an OPO, see e.g. D2 and the prior art described on page 8, last paragraph to page 9 paragraph 1, which could be employed instead of the arrangement of D1 without requiring inventive skills.

Regenerative amplifiers configured to generate burst of ultrashort pulses at high repetition rates may also be known in the art, see e.g. D3 (paragraphs [0025] - [0038]) as well as US9531151 cited therein. However, these regenerative amplifiers have not been disclosed as being suitable for synchronously pumping an OPO, so that D3 does not incite a person skilled in the art to replace the repetition rate multiplier of D1 by a regenerative amplifier.

An OPO synchronously pumped by a regenerative amplifier is disclosed in D4, however, in D4 the non-linear crystal of the OPO is provided within the resonator of the regenerative amplifier, so that the pump pulses are not coupled out of the regenerative amplifier. Moreover, D4 does not provide a burst of signal/idler output pulses, instead only a single pulse is coupled out of the OPO by providing a switch for cavity dumping. D4 would therefore prompt to another different solution.

Consequently, a person skilled in the art facing the technical problem would not have arrived at the subject-matter of claim 1 without an inventive step. Instead, he would have been prompted to different solutions.

3 Further claims

3.1 Independent claim 16 relates to essentially the same subject-matter as claim 1 and differs from claim 1 mostly in wording and level of detail. As claim 16 also relates to an OPO pumped by bursts of pulses generated by a solid state regenerative amplifier, the subject-matter of claim 16 is also novel for similar reasons.

3.2 Claims 2-15 and 17 are dependent on claim 1 or 16, respectively, and as such also meet the requirements of novelty and inventive step.

Re Item VIII

Certain observations on the application

The claims as a whole are not concise because they comprise two independent claims 1 and 16 in the same category which essentially refer to one and the same solution with slightly different wording and level of detail and/or generalisation. The inconsistencies between these independent claims render unclear which features are essential for the definition of the invention.

Furthermore, claim 16 is not clear because it does not define the means which are essential for forming burst of pulses using a regenerative amplifier, namely that the regenerative amplifier is configured such that (using the wording of claim 1) by applying a voltage to both or one of the optical switches, seed pulses spaced apart by a time interval 1/f3, are trapped inside the resonator. Without this feature it is impossible to obtain time intervals T1, T2 between adjacent bursts which are larger (e.g. larger than 100 µs) than the time interval of the pulses of the laser oscillator (500 MHz corresponding to 2ns) .