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Datasheet for the decision of 21 February 2019

Case Number: T 0795/15 - 3.4.02

Application Number: 11723587.9

Publication Number: 2569669

IPC: G02F1/35, G02F1/39

Language of the proceedings: EN

Title of invention:
OPTICAL PARAMETRIC GENERATOR BASED ON A SLANT- STRIPE PERIODICALLY POLED NONLINEAR MATERIAL WITH OPTIMISED LATERAL OUTPUT COUPLING OF A TERAHERTZ SIGNAL

Applicant:
University Court of The University of St Andrews

Headword:

Relevant legal provisions:
EPC Art. 54(1), 54(2), 84, 123(2)

Keyword:
Novelty - (no) - main request and auxiliary requests 1 to 4
Amendments - added subject-matter (yes) - auxiliary requests 2 to 4
Claims - clarity (no) - result to be achieved - auxiliary requests 5 and 6

Decisions cited:
T 0032/82

Catchword:

Europäisches Patentamt
European Patent Office
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Beschwerdekammern

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Case Number: T 0795/15 - 3.4.02

D E C I S I O N
of Technical Board of Appeal 3.4.02
of 21 February 2019

Appellant: (Applicant)	University Court of The University of St Andrews College Gate North Street St Andrews Fife KY16 9AJ (GB)
Representative:	Walker, Stephen Lincoln IP 9 Victoria Street Aberdeen AB10 1XB (GB)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 27 October 2014 refusing European patent application No. 11723587.9 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	R. Bekkering
Members:	A. Hornung
	B. Müller

Summary of Facts and Submissions

I. The applicant appealed against the decision of the examining division refusing European patent application No. 11723587.9 on the basis of Articles 84 and 56 EPC.

II. The appellant, with the statement setting out the grounds of appeal, requested that the decision under appeal be set aside and a patent be granted on the basis of the claims according to a new main request or a new auxiliary request 1 submitted with that statement.

III. In response to the summons to oral proceedings, the appellant, with a letter of 21 January 2019, filed new auxiliary requests 2 to 6.

IV. In a further letter dated 8 February 2019, the appellant informed the board that it would not be attending the oral proceedings and requested that a decision be issued based on the main request and on the auxiliary requests 1 to 6.

V. Oral proceedings were held on 21 February 2019 in the absence of the duly summoned appellant.

VI. The present decision refers to the following document:

D1: "A pump enhanced ns-OPO for THz generation", D. Molter et al., 33rd conference on Infrared, millimeter and terahertz waves 2008, IEEE, 15 September 2008, pages 1-2; XP 031398037;

VII. Claims of the requests

Main request

Independent claim 1 according to the main request reads as follows:

"An optical parametric device comprising a slant-stripe periodically poled nonlinear material (13) that is operable to generate two pairs of signal and idler waves in response to non-linear interaction with a pump wave, wherein the pump, signal and idler waves of each solution fulfil the phase matching condition, the non-linear interaction being such that the pump and idler waves are collinear and the signal wave is non-collinear relative to the pump and idler waves in each of the pairs, wherein a first one of the signal/idler wave pairs has a lower oscillation threshold than a second one of the signal/ idler wave pairs, and wherein the slant-stripe periodically poled nonlinear material has a grating period and a grating angle selected to ensure that the signal wave of the first, lower oscillation threshold signal/ idler wave pair is incident on a side face of the slant-stripe periodically poled nonlinear material at an angle that prevents total internal reflection."

First auxiliary request

Independent claim 1 according to the first auxiliary request is identical to claim 1 of the main request.

Second auxiliary request

Independent claim 1 according to the second auxiliary request reads as follows:

"An optical parametric oscillator comprising a slant-stripe periodically poled non-linear material (13) that is operable to generate two pairs of signal and idler waves in response to non-linear interaction with a pump wave,

wherein the non-linear material (13) is poled periodically to define a plurality of domains with a grating period and a grating angle, the grating period and the grating angle together defining a bipolar grating vector, wherein the pump wave defines a wave vector, wherein each of the signal and idler waves of each signal/idler wave pair defines a corresponding wave vector, wherein the grating vector, the wave vector of the pump wave, and the wave vectors of the signal and idler waves of a first one of the signal/idler wave pairs fulfil a condition for quasi-phase matching of the non-linear interaction between the non-linear material (13) and the pump wave, and wherein the grating vector, the wave vector of the pump wave, and the wave vectors of the signal and idler waves of a second one of the signal/idler wave pairs also fulfil the condition for quasi-phase matching of the non-linear interaction between the non-linear material (13) and the pump wave, the non-linear interaction being such that the pump and idler waves are collinear and the signal wave is non-collinear relative to the pump and idler waves in each of the signal/idler wave pairs, wherein the first one of the signal/idler wave pairs has a lower oscillation threshold than the second one of the signal/idler wave pairs, and wherein the grating period and the grating angle are selected to ensure that the signal wave of the first, lower oscillation threshold signal/idler wave pair is incident on a side face of the slant-stripe periodically poled non-linear material (13) at an angle that prevents total internal reflection for a given medium external to the non-linear material (13) and in the absence of any output coupling devices external to the non-linear material (13)."

Third and fourth auxiliary requests

Independent claim 1 according to the third and the fourth auxiliary requests is identical to claim 1 of the second auxiliary request.

Fifth auxiliary request

Independent claim 1 according to the fifth auxiliary request reads as follows:

"An optical parametric oscillator comprising:

a slant-stripe periodically poled non-linear material (13) that is operable to generate two pairs of signal and idler waves in response to non-linear interaction with a pump wave, wherein the non-linear material (13) is poled periodically to define a plurality of domains with a grating period and a grating angle, the grating period and the grating angle together defining a bipolar grating vector, wherein the pump wave defines a wave vector, wherein each of the signal and idler waves of each signal/idler wave pair defines a corresponding wave vector, wherein the grating vector, the wave vector of the pump wave, and the wave vectors of the signal and idler waves of a first one of the signal/idler wave pairs fulfil a condition for quasi-phase matching of the non-linear interaction between the non-linear material (13) and the pump wave, and wherein the grating vector, the wave vector of the pump wave, and the wave vectors of the signal and idler waves of a second one of the signal/idler wave pairs also fulfil the condition for quasi-phase matching of the non-linear interaction between the non-linear material (13) and the pump wave, the non-linear interaction being such that the pump and idler waves are collinear and the signal wave is non-collinear relative to the pump and idler waves in each of the signal/idler pairs, wherein the first one of the signal/idler pairs has a lower

oscillation threshold than the second one of the signal/ idler pairs, and the second, higher oscillation threshold signal wave is incident on a side face of the slant-stripe periodically poled non-linear material (13) at an angle that prevents total internal reflection;

an idler cavity, wherein the non-linear material (13) is located in the idler cavity; and

one or more optical elements located in the idler cavity for selecting the second signal wave for extraction from the slant-stripe periodically poled non-linear material (13) by increasing in operation the oscillation threshold of the first signal wave and its associated idler wave above the oscillation threshold of the second signal wave and its associated idler wave,

wherein the one or more optical elements are operable to change the relative magnitudes of losses associated with the two idler waves in the idler cavity so that the only idler wave generated corresponds to the second signal wave, and

wherein the one or more optical elements are operable to suppress oscillation on the lower threshold one of the two idler waves by increasing the losses associated with the lower threshold one of the two idler waves in the idler cavity relative to the losses associated with the higher threshold one of the two idler waves in the idler cavity."

Sixth auxiliary request

Independent claim 1 according to the sixth auxiliary request differs from claim 1 of the fifth auxiliary request in that it comprises the following additional feature:

"and wherein the non-linear material (13) is located within a cavity of a pump laser, which pump laser generates the pump wave".

Reasons for the Decision

1. Main request

1.1 The subject-matter of claim 1 lacks novelty with respect to the disclosure of D1 (Article 54(1) and (2) EPC) essentially for the same reasons as provided in point 6.3 of the communication annexed to the summons to oral proceedings.

It is uncontested by the applicant that D1 discloses all the features of claim 1, except for the feature according to which the slant-stripe periodically poled nonlinear material has a grating period and a grating angle selected to ensure that the signal wave of the first, lower oscillation threshold signal/idler wave pair is incident on a side face of the slant-stripe periodically poled nonlinear material at an angle that prevents total internal reflection (see *inter alia* the paragraph bridging pages 2 and 3 of the grounds of appeal and the fourth but last paragraph on page 4 of the appellant's letter of reply dated 21 January 2019).

In addition to the uncontested features, D1 also discloses "experiments using periodically poled lithium niobate (PPLN) in order to realize a powerful nanosecond OPO with *output* in the THz frequency range" (see D1, page 1, left column, first paragraph). For THz radiation being output coupled, it is implicit that it is not absorbed in the

nonlinear material and that, at the interface between the nonlinear material and the surrounding material, it is incident at an angle that prevents total internal reflection. In order to be incident at an angle that prevents total internal reflection, it is implicit that the nonlinear material has a grating period and a grating angle adequately selected.

Moreover, according to the k-vector diagram at the top of the first figure of D1, the two THz radiations $\mathbf{k}_{THz}$ are incident at a side face of the nonlinear material. The radiation shown at the left side of the figure is emitted perpendicularly with respect to the crystal surface (see D1, page 1, right column, first paragraph). The radiation shown at the right side of the figure has a lower threshold than the one shown at the left side. In order to be useable outside the crystal, i.e. in order to be effectively output coupled, the radiation with the lower threshold requires appropriate crystal cuts or other outcoupling techniques (see D1, page 1, right column, first paragraph).

It follows that D1 discloses a slant-stripe periodically poled nonlinear material that has a grating period and a grating angle compatible with the possibility of output coupling the lower threshold THz radiation by preventing total internal reflection. In order to anticipate a claimed feature, it is not required that D1 discloses the *concrete realization* of the claimed feature. Since the claimed feature under debate is mentioned in D1 as being a possible realization, it is indeed anticipated by D1.

1.2 The appellant presented the following counter-arguments:

1.2.1 By referring to various passages of D1, the appellant essentially argued that D1 did not describe an experiment

in which the lower threshold THz radiation was effectively output coupled (see e.g. grounds of appeal, pages 2 to 4; letter of reply dated 21 January 2019, page 4). The lower threshold THz radiation shown at the right side in the first figure of D1 was either absorbed in the nonlinear material or totally internally reflected at the interface with the external material. The disclosure in D1, page 1, left column, first paragraph, of an "output in the THz frequency range" "may be regarded as the ultimate objective or goal of the experiments without implying that the ultimate objective or goal has actually been reached" (letter of reply dated 21 January 2019, page 4, fourth paragraph).

As explained in point 1.1 above, the board cannot follow this argument because D1 explicitly describes the conditions under which the lower threshold THz radiation can effectively be coupled out, i.e with "appropriate crystal cuts or other outcoupling techniques" (see D1, page 1, right column, first paragraph). This has not been contested by the appellant. The disclosure in D1 of how to achieve the possible realization of the claimed feature under debate is sufficient to anticipate it, irrespective of whether the feature has been concretely realized in one of the experiments of D1 or not.

1.2.2 The applicant further contended that "by carefully selecting the grating period and grating a angle (...), the present invention allows output coupling of the THz wave (...) without the need for external output coupling devices" (see grounds of appeal, page 3, fourth paragraph, last sentence). The design of these intrinsic features of the non-linear material ensured that total internal reflection was avoided.

The board is not convinced by these arguments because claim 1 is not so limited as to exclude output coupling via external output coupling devices. The incidence angle that prevents total internal reflection, i.e. the critical angle, depends on the refractive index of the material external to the non-linear material. If the material surrounding the non-linear material is not air but, for instance, a silicon prism as mentioned in D1, page 2, left column, last sentence, then the critical angle becomes larger. However, claim 1 does not specify any limitation on the critical angle or on the type of surrounding material. Claim 1 covers both possibilities where the surrounding material is either air or an optical element.

Furthermore, claim 1 being directed to a device, the mere intention or objective underlying the design of the grating does not limit the scope of protection of claim 1 with respect to the design of the grating of D1. Indeed, no structural, distinguishing feature over D1 is implied by the wording of claim 1 "... has a grating period and a grating angle selected to ensure ... an angle that prevents total internal reflection".

1.2.3 In its letter of reply dated 21 January 2019, page 3, point 1.2.3, first paragraph, the appellant, referring to section 6.3.2 of the board's communication annexed to the summons to oral proceedings, based an argument on the statement "[i]f it is accepted that the OPO of D1 generates a THz signal inside the non-linear crystal, but that the terahertz signal is not coupled out of the non-linear crystal, then ...".

The board notes that the appellant apparently misunderstood the board's sentence "[f]rom the fact that D1 does not disclose that an output was effectively coupled out..." in point 6.2.3 of its communication.

Indeed, the board merely acknowledged that D1 did not disclose an experiment in which an output was effectively, i.e. concretely, coupled out. As clarified in the subsequent paragraph of the board's communication, "[i]n order to anticipate a claimed feature, it is not required that the prior art document discloses the *concrete realization* of the claimed feature. In general, if the feature of a claim is mentioned in the prior art as being a possible realization, it is anticipated by said prior art".

1.3 In conclusion, the subject-matter of claim 1 lacks novelty with respect to the disclosure of D1 (Article 54(1) EPC).

2. First auxiliary request

Since independent claim 1 according to the first auxiliary request is identical to claim 1 of the main request, the subject-matter of claim 1 lacks novelty with respect to the disclosure of D1 (Article 54(1) and (2) EPC) for the same reasons as given in point 1. above.

3. The board, exercising its discretion under Article 13 RPBA, has decided to admit auxiliary requests 2 to 6 into the proceedings.

4. Second auxiliary request

4.1 Amendments

Claim 1 contains subject-matter which extends beyond the content of the application as filed, contrary to the requirements of Article 123(2) EPC.

4.1.1 Claim 1 has been amended with respect to claim 1 of the main request essentially in that (i) the technical meaning

of the expressions "phase matching solution", "grating period" and "grating angle" and their inter-relationship has been clarified and in that (ii) the phrase "in the absence of any output coupling devices external to the non-linear material" has been added at the end of claim 1.

The second amendment (ii), however, cannot be derived directly and unambiguously from the application as originally filed. On the contrary, the application as originally filed refers to an interface between a nonlinear medium and silicon prims, i.e. with the help of an output coupling device external to the nonlinear material (see page 10, lines 33 to 35, and page 12, lines 1 to 8 of the application as originally filed).

4.1.2 According to the appellant, the basis for the second amendment (ii) is to be found in "previous claim 1, original claims 1 and 2, and at page 10, lines 26 to 30" (see letter of reply dated 21 January 2019, page 5, second and third paragraphs).

The board is not convinced that the recited passages constitute a basis for the amended feature. Indeed, claims 1 and 2 as originally filed leave open the nature of the medium surrounding the nonlinear material. The phrase on page 10, lines 29 and 30, "[t]his can be achieved by correct design of the slant-stripe nonlinear medium", merely teaches that the design of the grating period and the grating angle has to take account of the critical angle determined *inter alia* by the refractive index of the medium surrounding the nonlinear material. However, this phrase leaves undefined whether the surrounding medium is air, silicon or any other material.

In case that the phrase "previous claim 1", used by the appellant in its letter of reply dated January 2019,

referred to claim 1 of the main request, such a "previous claim 1" can formally not constitute an allowable basis under Article 123(2) EPC for the second amendment (ii) since it was not originally filed.

4.2 Novelty

Notwithstanding the infringement of Article 123(2) EPC, the subject-matter of claim 1 lacks novelty with respect to the disclosure of D1 (Article 54(1) and (2) EPC).

4.2.1 The features relating to the two amendments (i) and (ii) of claim 1 (see point 4.1.1 above) are not suitable to render the subject-matter of claim 1 novel over D1 for the following reasons:

The first amendment (i) merely constitutes a clarification of the claimed subject-matter. Rendering more precise the definition of the expressions "phase matching solution", "grating period" and "grating angle", used in claim 1 of the main request, does not further limit the scope of present claim 1. Anyway, the amended definitions also apply to the grating of D1. The appellant did also not argue novelty of the subject-matter of claim 1 based on the features relating to the first amendment (i).

The feature corresponding to the second amendment (ii) of claim 1, i.e. "(...) in the absence of any output coupling devices external to the non-linear material (13)", is not novel over D1. Indeed, D1, page 1, right column, first paragraph discloses a technique for coupling out the THz radiation based on "appropriate crystal cuts". This technique of D1 is not based on an output coupling device external to the non-linear material, but on an appropriate design of the grating parameters and the crystal cuts, both aspects relating to the nonlinear material itself.

4.2.2 The appellant presented no counter-argument relevant to the board's reasoning of lack of novelty.

5. Third and fourth auxiliary requests

Since independent claim 1 according to the third and fourth auxiliary requests is identical to claim 1 of the second auxiliary request, claim 1 of the third and fourth auxiliary requests also contains subject-matter which extends beyond the content of the application as filed, contrary to the requirement of Article 123(2) EPC, for the same reasons as given in points 4.1 above.

Moreover, the subject-matter of claim 1 of the third and fourth auxiliary requests lacks novelty with respect to the disclosure of D1 (Article 54(1) and (2) EPC) for the same reasons as given in points 4.2 above

6. Fifth auxiliary request

Claim 1 lacks clarity within the meaning of Article 84 EPC, essentially for the same reasons as provided in point 6.2, second and third paragraphs, of the communication annexed to the summons to oral proceedings.

6.1 Claim 1 of the fifth auxiliary request corresponds to the independent claim 4 of the main request, wherein essentially the following amendments have been carried out (see letter of reply, dated 21 January 2019, point 1.3.1):

(a) The technical meaning of the expressions "phase matching solution", "grating period" and "grating angle" and their inter-relationship has been clarified in the same manner as in the amendment (i) of claim 1

of the second auxiliary request (see point 4.1.1 above).

(b) According to the letter of reply, dated 21 January 2019, page 6, third paragraph, "[s]everal additional limitations relating to the location, nature and function of the one or more optical elements" have been added to claim 1. These amendments recite *inter alia*:

(b1): "an idler cavity, wherein the non-linear material (13) is located in the idler cavity",

(b2): "(...) by increasing in operation the oscillation threshold (...)",

(b3): wherein the one or more optical elements are operable to change the relative magnitudes of losses associated with the two idler waves in the idler cavity so that the only idler wave generated corresponds to the second signal wave",

(b4): "wherein the one or more optical elements are operable to suppress oscillation on the lower threshold one of the two idler waves by increasing the losses associated with the lower threshold one of the two idler waves in the idler cavity relative to the losses associated with the higher threshold one of the two idler waves in the idler cavity".

As stated in the communication annexed to the summons to oral proceedings with respect to claim 4 of the main request, present claim 1, too, is "unclear since it attempts to define the claimed subject-matter in terms of

the result to be achieved, i.e. "increasing the oscillation threshold of the first signal wave", instead of defining it in terms of structural features responsible for achieving the claimed result (Article 84 EPC)".

This is contrary to the established jurisprudence of the boards of appeal according to which a claim "must define clearly the object of the invention, that is to say indicate all the essential features thereof. As essential features have to be regarded all features which are necessary to obtain the desired effect or, differently expressed, which are necessary to solve the technical problem with which the application is concerned" (see T 32/82, point 15 of the Reasons).

In the present case, according to the description, page 12, line 32 to page 14, line 19, specific optical elements, such as an etalon or a resonant reflector, are necessary to obtain the desired effect of an increased oscillation threshold of the first signal wave. These essential features, however, are missing in present claim 1, so that the claim is unclear.

Amendment (a) manifestly cannot contribute to resolve the clarity issue at stake since it merely provides a more precise definition of the grating parameters.

Amendment (b) does also not define how the oscillation threshold of the first signal wave is actually increased. Indeed, (b1) does manifestly not increase the oscillation threshold of the first signal since it defines an aspect of the idler wave and not the signal waves; (b2) merely clarifies the general claim wording; (b3) and (b4) essentially reformulate the result to be achieved without providing additional information about how the result is achieved.

6.2 The appellant, in its letter of reply dated 21 January 2019, did not provide any convincing argument against this clarity objection, which was raised by the board in the communication annexed to the summons to the oral proceedings (see point 6.2 of the communication, second and third paragraphs). The appellant confined its written submission to a description of the basis of the amendments carried out and to the statement that, therefore, the claim "recites several additional limitations relating to the location, nature and function of the one or more optical elements" (see letter of reply dated 21 January 2019, page 6, third paragraph). However, these limitations, if any at all, do not resolve the issue of lack of essential features for the reasons given above.

7. Sixth auxiliary request

Claim 1 lacks clarity within the meaning of Article 84 EPC, essentially for the same reasons as claim 1 of the fifth auxiliary request (see point 6.1 above).

Indeed, present claim 1 differs from claim 1 of the fifth auxiliary request only in that it incorporates the additional feature "wherein the non-linear material (13) is located within a cavity of a pump laser, which pump laser generates the pump wave". This additional feature defines an intracavity arrangement of the optical parametric oscillator but has no effect on raising the oscillation threshold of the first signal wave above the oscillation threshold of the second signal wave. Therefore, present claim 1 is still unclear since it attempts to define the claimed subject-matter in terms of the result to be achieved, i.e. "increasing in operation the oscillation threshold of the first signal wave",

instead of defining it in terms of structural features responsible for achieving the claimed result.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

M. Kiehl R. Bekkering

Decision electronically authenticated