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Language of the proceedings: EN

Title of invention:
Control of relaxation oscillations in intracavity optical parametric oscillators

Applicant:
University Court of The University of St Andrews

Headword:

Relevant legal provisions:
EPC Art. 56, 123(2)

Keyword:
Amendments - allowable (no)
Inventive step - (no)

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Catchword:

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Case Number: T 1021/18 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 18 February 2020

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 17 October 2017 refusing European patent application No. 13177766.6 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	G. Eliasson
Members:	M. Stenger
	G. Decker

Summary of Facts and Submissions

I. The appeal concerns the decision of the Examining Division to refuse European application No. 13177766, which is a divisional application of European application No. 09784820.

II. Reference is made to the following documents:

D3: US 5 796 761 A

D5: Turnbull G. et al.: "Transient Dynamics of CW Intracavity Singly Resonant Optical Parametric Oscillators", IEEE Journal of Quantum Electronics, Vol. 35, No. 11, pages 1666 - 1672, November 1999, ISSN: 0018-9197, XP000902533

D6: WO 2007/100433 A2

III. The appellant requested in the grounds of appeal that the contested decision be set aside and that a patent be granted on the basis of a main request or on the basis of one of auxiliary requests 1 to 9. All requests were filed with the grounds for appeal.

IV. In a communication preparing the oral proceedings, the Board expressed its preliminary opinion that the original application did not contain a basis according to Article 123(2) EPC for the feature that the variable linear loss means were located in the pump-wave cavity *and* in the down converted wave cavity (see point 6 of that communication).

Further, in the same communication, the Board expressed its preliminary opinion that D3 would incite the skilled person to integrate any of the features relating to the variable non-linear loss means comprised in the independent claims of the main request and auxiliary requests 1 to 7 into the system disclosed in D5 (see points 3.3, 5.1 and 5.2 of that communication).

V. The appellant did not reply thereto in substance. Instead, the representative announced with a letter dated 14 February 2010 that he would not be attending the oral proceedings scheduled for 18 February 2020. Oral proceedings were held in absence of the appellant.

VI. When citing passages of the application in the grounds of appeal, the appellant referred to the original parent application. In this decision, the corresponding passages of the published (divisional) application are used instead.

VII. Claim 1 of the main request has the following wording (labeling (m1), (m2), (a1)... added by the Board):

(m1) *A continuous wave intra-cavity optical parametric oscillator including:*

(m2) *a non-linear material for generating down converted coherent radiation in response to a pump wave generated by a laser gain medium;*

a pump-wave cavity for supporting the pump wave, and a down converted wave cavity associated with the down

converted coherent radiation, the non-linear material being located in both the pump-wave cavity and the down converted wave cavity;

(a1) *variable non-linear loss means for providing a variable non-linear loss for suppressing relaxation oscillations, wherein the variable non-linear loss means are variable in response to an electrical signal;*

(a2) *means for monitoring the intensity of one or other of the pump wave and the down converted radiation; and*

(a3) *means for varying the variable non-linear loss means so as to vary the non-linear loss in response to the monitored instantaneous intensity.*

VIII. Claim 1 of auxiliary request 1 differs from claim 1 of the main request in that feature (m2) is replaced by feature (m2') as follows (labeling (m2') added by the Board):

(m2') *a laser gain medium for generating a pump wave;*

a non-linear material for generating down converted coherent radiation in response to the pump wave, the down converted coherent radiation comprising a signal wave and an idler wave;

two coupled optical cavities, these being a pump-wave cavity for resonating the pump wave, and a down converted wave cavity for resonating the signal wave or the idler wave, wherein the non-linear material and the laser gain medium are located in the pump-wave cavity

and the non-linear material is also located in the down converted wave cavity;

IX. Claim 1 of auxiliary request 2 differs from claim 1 of the main request in that it comprises, after feature (a1), the additional feature (b) as follows (labeling added by the Board):

(b) *and are located in the pump wave cavity and/or the down converted wave cavity;*

X. Claim 1 of auxiliary request 3 differs from claim 1 of auxiliary request 1 in that it comprises, after feature (a1), feature (b) as defined above.

XI. Claim 1 of auxiliary request 4 differs from claim 1 of the main request in that it comprises, at its end, additional feature (c) as follows (labeling added by the Board):

(c) *wherein the variable non-linear loss means comprise an optical modulator within a cavity associated with one or another of the pump wave and the down converted radiation.*

XII. Claim 1 of auxiliary request 5 differs from claim 1 of auxiliary request 1 in that it comprises, at its end, additional feature (c) as defined above.

XIII. Claim 1 of auxiliary request 6 differs from claim 1 of the main request in that it comprises, after feature

(a1), additional feature (b') as follows (labeling added by the Board):

(b') *and are located in the pump-wave cavity;*

XIV. Claim 1 of auxiliary request 7 differs from auxiliary request 1 in that it comprises, after feature (a1), additional feature (b') as defined above.

XV. Claim 1 of auxiliary request 8 differs from claim 1 of auxiliary request 2 in that feature (m1) is replaced by feature (m1') as follows, and in that it comprises at its end feature (d) as follows (labeling added by the Board):

(m1') *A method for suppressing relaxation oscillations in a continuous wave intra-cavity optical parametric oscillator, wherein the continuous wave optical parametric oscillator includes:*

(d) *wherein the method comprises using the means for varying the non-linear loss to control the non-linear loss means in response to the monitored instantaneous intensity so that the non-linear loss is non-linearly proportional to the monitored instantaneous intensity.*

XVI. Claim 1 of auxiliary request 9 differs from claim 1 of auxiliary request 3 in that feature (m1) is replaced by feature (m1') as defined above and in that it comprises at its end feature (d) as defined above.

XVII. The relevant arguments of the appellant as apparent from the grounds of appeal may be summarised as follows:

(a) Document D3 failed to disclose a variable non-linear loss means for providing a variable non-linear loss (see grounds of appeal, points 1.3 and 1.4.1.1).

(b) The skilled person would not have any motivation to combine D5 and D3 because D5 already outlines six specific techniques for use in suppressing relaxation oscillations in a CW singly-resonant intra-cavity OPO. The skilled person would thus have no motivation to seek an alternative technique thereto (see grounds of appeal, point 1.4.1.3).

(c) An intra-cavity optical parametric oscillator was different from and more complex than a laser alone. Therefore, the solution for suppressing relaxation oscillations presented in that document could not be assumed to be appropriate for an intra-cavity OPO (see grounds of appeal, the part of point 1.4.1.3 from page 8, penultimate paragraph to page 9, fourth paragraph).

(d) The general statement on page 1671, left-hand column of D5 relating to the *various other techniques* could not be regarded as being indicative of a *reasonable expectation of success* rather than a mere *hope to succeed* (see grounds of appeal, the part of point 1.4.1.3 in the fifth paragraph of page 8).

(e) Two of the authors of D5 were named inventors for the present application and the long time of

approximately nine years it took them to invent the intra-cavity OPO of claim 1 demonstrated that a long-felt need for such an OPO existed between 1999 and 2008, indicating an inventive step (see grounds of appeal, point 1.4.1.4).

(f) The *either/or* construction in paragraph [46] of the published application should be interpreted to be an *inclusive or* because [46] also related to the embodiments described in paragraphs [30] and [31] shown in figures 5 (a) and 5 (b). In these embodiments, the additional non-linear loss means were located in the common part of the pump laser cavity and of the down converted wave cavity, thereby providing a basis for *variable non-linear loss means* being *located in the pump wave cavity and/or the down converted cavity* (see grounds of appeal, point 3.2.1).

Reasons for the Decision

1. The appeal is admissible.

2. The application

The application relates to intra-cavity optical parametric oscillators (OPOs), i.e. to OPOs where the non-linear material causing the parametric frequency conversion is located in the pump wave cavity. The purpose of the application is to provide an intra-cavity OPO with a stable output by reducing or eliminating relaxation oscillations. This reduction is achieved by providing a non-linear loss in addition to

that provided by the normal operation of the OPO (paragraph [14] of the published application).
This additional non-linear loss is provided by means for varying a non-linear loss in response to an electrical signal corresponding to the instantaneous intensity monitored in one of the cavities of the OPO (paragraph [44] of the published application).

3. Document D5

Document D5 is an academic article relating to the study of relaxation oscillations in intra-cavity optical parametric oscillators (abstract). Suitable techniques to suppress such relaxation oscillations are discussed (part V. C. *Implications to Stable CW ICSRO Operation*).
Two of the inventors of the present application (M.H. Dunn and D.J.M. Stothard) are among the authors of D5, as pointed out by the appellant (grounds of appeal, point 1.4.1.4).

4. Preliminary remark concerning additional non-linear loss

The invention aims at reducing relaxation oscillations in order to make the output of the OPO more stable as mentioned above. The problem of relaxation oscillations in OPOs has been generally known at the relevant priority date. For example, D5 concerns this problem and suggests suitable solutions as noted above.

The application indicates in a very general manner that this problem can be solved by providing *any* non-linear

loss in addition to that provided by the normal operation of the OPO itself (paragraph [14]).

No details are given as to the *magnitude*, *shape* or *power dependence* of the additional non-linear loss that is required to achieve a reduction of relaxation oscillations. The *amount* of the reduction achieved by the additional non-linear loss is not indicated in the application, either.

It must be concluded that *any* means producing non-linear loss in an intra-cavity OPO in addition to the non-linear loss provided by normal operation of the OPO have to be considered to correspond to *non-linear loss means for suppressing relaxation oscillations* within the meaning of the application.

5. Auxiliary requests 2, 3, 8 and 9, feature (b), Article 123(2) EPC

Figure 9 of the original application discloses a location of the variable non-linear loss means 36 in the pump-wave cavity only.

Further, the penultimate sentence of paragraph [46] of the published application discloses that the variable (additional) non-linear loss means can be located *in the optical cavity of either the optical parametric oscillator or the pump laser within which the OPO is located*. This passage therefore provides a basis for the variable non-linear loss means being located *either* in the optical cavity of the OPO, that is the down converted wave cavity, *or* in the optical cavity of the pump laser, that is the pump laser cavity, but not in *both* cavities.

The same applies to the formulation used in paragraph [26] of the original application that the optical modulator is comprised within a cavity associated with *one or other* of the intra-cavity fields.

Paragraphs [30] and [31] of the published application relate to means for providing a(n additional) non-linear loss that are *part of or integral with* the optical parametric oscillator crystal (see also Clause 8 of the published application). That is, the location of these means is by definition determined by the location of the OPO crystal; no other locations are possible.

The skilled person would thus not consider that the passages in [26] and [46], in which different possible locations of means for providing an additional non-linear loss are discussed, apply to such means that are *integral* with the OPO crystal.
Hence, the combination of paragraphs [46] and [30], [31] does not provide a basis for the location of *variable non-linear loss means for providing an additional non-linear loss* that are *separate* from the OPO crystal and located in *both* the pump cavity *and* the down converted cavity, contrary to the argument of the appellant (see point XVII.(f) above).

In contrast to the content of the original application, however, one of the possibilities for the location of the variable non-linear loss means according to the *and/or* alternative formulation of feature (b) as defined above is a location of the variable non-linear loss means in *both* the pump wave cavity *and* the down converted wave cavity (which would correspond to a location between the beam splitter 22 and the mirror 18 in figure 9).

Thus, the independent claims of all requests that comprise feature (b) do not fulfil the requirements of Article 123(2) EPC.
This applies to auxiliary requests 2, 3, 8 and 9.

These requests are therefore not allowable. Consequently, there is no need to discuss them with respect to inventive step.

6. Main request, auxiliary requests 1 and 4 to 7, Article 56 EPC

6.1 D5, features (m1), (m2) and (m2')

The first features (m1), (m2) and (m2') of the independent claims of the main request and of auxiliary requests 1 and 4 to 7 do not go beyond what is inherent to a standard intra-cavity optical parametric oscillator as for example disclosed in D5.

More particularly, D5 discloses, in the wording of these features (see generally Figure 1 of D5 and the corresponding part of the description):

(m1) A continuous wave intra-cavity optical parametric oscillator (see title of D5) including:

(m2) a non-linear material (*PPLN*) for generating down-converted radiation in response to a pump wave generated by a laser medium ($NdYVO_4$);

a pump-wave cavity (*Laser Cavity*) for supporting the pump wave, and a down converted wave cavity (*Signal cavity*) associated with the down converted coherent

radiation, the non-linear material being located in both the pump-wave cavity and the down converted wave cavity (between the beam splitter *BS* and the mirror *M2*);

(m2') a laser gain medium ($NdYVO_4$) for generating a pump wave;

a non-linear material (*PPLN*) for generating down converted coherent radiation in response to the pump wave, the down converted coherent radiation comprising a signal wave and an idler wave (see abstract and page 1667, right-hand column, second paragraph);

two coupled optical cavities, these being a pump-wave cavity (*Laser Cavity*) for resonating the pump wave, and a down converted cavity (*Signal cavity*) for resonating the signal wave or the idler wave, wherein the non-linear material and the laser gain medium are located in the pump-wave cavity (between mirrors *M1* and *M2*) and the non-linear material is also located in the down converted wave cavity (between mirrors *M2* and *M3*);

Thus, D5 discloses features (m1), (m2) and (m2').

6.2 Features (a1), (a2), (a3), (b') and (c)

Each of the independent claims of the main request and of auxiliary requests 1 and 4 to 7 comprises features (a1), (a2) and (a3).
The independent claims of auxiliary requests 4 and 5 further comprise feature (c) and the independent claims of auxiliary requests 6 and 7 additionally comprise feature (b').

Thus, none of the independent claims of these requests goes beyond a combination of features (m1), (m2), (m2'), (a1), (a2), (a3), (b') and (c).

D5 discloses features (m1), (m2) and (m2') as argued above, but does not disclose features (a1), (a2), (a3), (b') and (c).

6.3 Technical effect / objective technical problem to be solved

The technical effect of (potentially differentiating) features (a1), (a2), (a3), (b') and (c) in combination is that the loss in the OPO may be changed depending on the monitored instantaneous intensity. This solves the objective technical problem to stabilise the intra-cavity OPO against relaxation oscillations of the pump wave.
The Board notes that this corresponds to the objective technical problem formulated by the Examining Division (see point II.b 1.4 of the contested decision).

6.4 Inventive step

6.4.1 Combining D5 with the teaching of D3

Document D5 addresses relaxation oscillations (see the paragraph bridging the left-hand column and the right-hand column of page 1668) and suggests to suppress them (page 1671, left-hand column, first paragraph of section V.C.).
To that end, D5 gives the general indication that "*[v]arious other techniques that have been suggested to suppress relaxation oscillations in lasers ... may also be of use*" in the intra-cavity OPO disclosed in D5. In addition, in the same sentence, some specific

techniques are listed: "*... such as injection seeding [10] and active electronic control [14]*" (page 1671, left-hand column, second paragraph of section V.C.).

The Board notes that these specific techniques are given as examples only ("*such as*"). Thus, the skilled person would certainly consider to use any of these specific techniques to suppress relaxation oscillation. However, there is no reason to assume that the skilled person would therefore discard other techniques previously employed to suppress relaxation oscillations in lasers, contrary to the argument of the appellant (see point XVII.(b) above).

It follows from the above that the skilled person, starting from D5, would be incited by that document itself to consider all possible techniques used to suppress relaxation oscillations in lasers to solve the objective technical problem as defined above, as already argued by the Examining Division (see point II.b 1.5 of the contested decision).

Document D3 discloses a laser where relaxation oscillations are suppressed (see abstract and column 5, lines 38 to 39). Thus, the teaching of this document relates to techniques used to suppress relaxation oscillations in lasers.

Further, document D3 discloses a Raman laser system including a laser pumping system 20 with a laser gain medium 22 (column 5, lines 19 to 23) in a laser pumping system cavity (see figure 3 and column 6, lines 49 to 55) and a down converted wave cavity (Raman resonator cavity 70, see figure 1) including a non-linear material (Raman medium 74, see column 5, lines 13 to 18).

The laser system of D3 therefore comprises some of the structural features of an intra-cavity OPO system such as the one disclosed in D5.
In addition, the requirements on the stability of the pulsed pump laser used in D3 are higher than the requirements on the stability of the CW laser used according to the application, as already argued by the Examining Division (see point II.b 1.6 of the contested decision).

Thus, although the Raman laser system of D3 is not identical to an intra-cavity OPO system such as the one described in D5 as argued by the appellant (see point XVII.(c) above), it is sufficiently similar to such a system so that the skilled person would not be dissuaded from considering the teaching of D3 when trying to solve the objective technical problem as defined above, contrary to that argument.

It follows from the above that the skilled person, starting from D5, would consider D3 when trying to solve the objective technical problem as defined above.

6.4.2 Teaching of D3

The skilled person would learn from D3 that relaxation oscillations can be suppressed by a feedback loop with the following three features in combination:

(i) providing a photodiode 34 in the laser pumping system for monitoring the instantaneous intensity of the input beam 24 (by measuring a small portion 32 of that beam, see figure 3 of D3) and providing an electrical signal 36 (column 5, lines 47 to 55 of D3);

(ii) providing an acousto-optic modulator (AOM) 46 being located in the cavity of the input beam (see figure 3), the loss caused by the AOM being variable in response to the electrical signal 36 (see column 5, lines 56 to 61 of D3); and by

(iii) providing means for varying the loss caused by the AOM in response to the monitored instantaneous intensity of the input beam (column 5, line 61 to column 6, line 8 of D3).

The success of using a feedback loop according to features (i), (ii) and (iii) in suppressing relaxation oscillations in a similar technical situation (as argued above) would provide the skilled person with a reasonable expectation of success going beyond a mere hope to succeed, contrary to the arguments of the appellant (see point XVII.(d) above).

6.4.3 Adapting the intra-cavity OPO disclosed in D5

The skilled person would thus adapt the system of D5 by including features (i), (ii) and (iii) without exercising an inventive step.

The Board notes that, as argued by the Examining Division (see the first paragraph on page 13 of the contested decision), the losses of an AOM depend in a non-linear manner on the input electrical RF *power* as evidenced by D6 (see figure 8 and paragraph [75]). Therefore, an AOM has to be considered as being a *non-linear loss means providing a variable non-linear loss* within the very general meaning of the term as used in the present application (see point 4 above), contrary to the argument of the appellant (see point XVII.(a) above).

Further, in the wording of the present application, the photodiode 34 of D3 corresponds to the *means for monitoring the intensity of the pump wave* and the cavity of the input beam of D3 corresponds to the *pump-wave cavity* of the present application.

It follows therefrom that
- feature (i) as defined above corresponds to feature (a2),
- feature (ii) as defined above corresponds to a combination of features (a1), (b') and (c), and
- feature (iii) as defined above corresponds to feature (a3).

Thus, by adapting the system of D5 by integrating features (i), (ii) and (iii), the skilled person would integrate all features (a1), (a2), (a3), (b') and (c) into the OPO of D5, thereby arriving at an intra-cavity OPO comprising all features (m1), (m2), (m2'), (a1), (a2), (a3), (b') and (c) as defined above.

As mentioned above, the skilled person would do so without the exercise of an inventive step within the meaning of Article 56 EPC.

6.5 Conclusion concerning the main request and auxiliary requests 1 and 4 to 7

Starting from D5, the skilled person would arrive at an intra-cavity OPO comprising all features (m1), (m2), (m2'), (a1), (a2), (a3), (b') and (c) as defined above without the exercise of an inventive step according to Article 56 EPC by taking into account the teaching of D3.

Each of the independent claims of the main request and of auxiliary requests 1, 4, 5, 6 and 7 consists of only a sub-combination of features (m1), (m2), (m2'), (a1), (a2), (a3), (b') and (c) as mentioned above.

Consequently, the subject-matter of each of these claims is not inventive within the meaning of Article 56 EPC.

The Board notes that the long-felt need mentioned by the appellant (see point XVI.(e) above) is only a secondary indication and therefore, in accordance with the Case Law of the Boards of Appeal, only of importance in cases of doubt (Case Law of the Boards of Appeal, 9th edition 2019, section I.D.10.1.), which is not the case here.

7. The independent claims of auxiliary requests 2, 3, 8 and 9 do not fulfil the requirements of Article 123(2) EPC. The subject-matter of the independent claims of the main request, of auxiliary request 1 and of auxiliary requests 4 to 7 is not inventive within the meaning of Article 56 EPC.
For these reasons, none of the requests is allowable with respect to the EPC. Thus, the appeal must fail.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated