Internal distribution code:

(A) [-] Publication in OJ
(B) [-] To Chairmen and Members
(C) [-] To Chairmen
(D) [X] No distribution

Datasheet for the decision of 5 March 2020

Case Number: T 0914/16 - 3.4.03

Application Number: 03705133.1

Publication Number: 1475678

IPC: G03H1/04

Language of the proceedings: EN

Title of invention:
METHOD FOR PRODUCING A HOLOGRAM BY PICOSECOND LASER

Patent Proprietor:
Japan Science and Technology Agency

Opponent:
Bundesdruckerei GmbH

Headword:

Relevant legal provisions:
EPC 1973 Art. 54, 56
EPC Art. 123(2), 101(3)(a)

Keyword:

Amendments - allowable (yes)
Novelty - main request - yes
Inventive step - main request - yes

Decisions cited:

Catchword:

Beschwerdekammern
Boards of Appeal
Chambres de recours

Boards of Appeal of the
European Patent Office
Richard-Reitzner-Allee 8
85540 Haar
GERMANY
Tel. +49 (0)89 2399-0
Fax +49 (0)89 2399-4465

Case Number: T 0914/16 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 5 March 2020

Appellant: (Patent Proprietor)	Japan Science and Technology Agency 1-8, Honcho 4-chome Kawaguchi-shi, Saitama 332-0012 (JP)
Representative:	dompatent von Kreisler Selting Werner - Partnerschaft von Patent- und Rechtsanwälten mbB Deichmannhaus am Dom Bahnhofsvorplatz 1 50667 Köln (DE)
Respondent: (Opponent)	Bundesdruckerei GmbH Oranienstr. 91 10969 Berlin (DE)
Representative:	Obst, Bernhard Patentanwälte Bressel und Partner mbB Postdamer Platz 10 10785 Berlin (DE)
Decision under appeal:	**Decision of the Opposition Division of the European Patent Office posted on 10 February 2016 revoking European patent No. 1475678 pursuant to Article 101(3)(b) EPC.**

Composition of the Board:

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

Summary of Facts and Submissions

I. The appeal of the appellant/proprietor concerns the decision of the Opposition Division to revoke European patent No. EP1475678.

II. The opposition was based on the grounds of opposition under Article 100(a) and (c) EPC.

III. It is referred to the following documents:

D1: EP 1162519 A

D4: K. Kawamura et al.: "Holographic writing of volume-type micrograting in silica glass by a single chirped laser pulse", Applied Physics Letters, Vol. 81, No. 6, 5 August 2002 (2002-08-05), pages 1137-1139

D8: M.P. Kalachnikov et al.: "100-Terawatt Titanium-Sapphire Laser System", Laser Physics, Vol. 12, No. 2, February 2002 (2002-02), pages 368-374

D9: M. Pessot et al.: "1000 Times Expansion/ Compression of Optical Pulses for Chirped Pulse Amplification", Optics Communications, Vol. 62, No. 6, 15 June 1987 (1987-06-15), pages 419-421

D10: WO 95/27587 A1

IV. At the end of the oral proceedings before the Board, the proprietor requested that the contested decision be set aside and that the patent be maintained on the basis of a main request or on the basis of auxiliary requests 1, 1a, 2a, 2 or 2b. All requests were filed during the appeal proceedings.

V. The main request comprises the following documents:

Claims: Nos. 1 to 7 according to the main request filed with the statement setting out the grounds of appeal;

Description: as in the patent specification; and

Drawings: as in the patent specification.

VI. At the end of the oral proceedings before the Board, the opponent requested that the decision of the Opposition Division be maintained and that the appeal be dismissed.

VII. The main request corresponds to the auxiliary request discussed during the first instance opposition proceedings. The Opposition Division came to the conclusion that the subject-matter of independent claim 1 of that request complied with the requirements of Articles 100(c)/123(2) EPC (points 2.1.1 to 2.1.4 of the impugned decision), but lacked an inventive step according to Article 56 EPC in view of D1 combined with the common general knowledge as exemplified by D8 to D10 (points 2.2.2.1 to 2.2.2.7 of the contested decision).

VIII. Claim 1 of the main request has the following wording (labelling added by the Board):

A method of producing a hologram in a non-photosensitive material through a two-beam laser interfering exposure process, said method comprising:

(a) *emitting a coherent femtosecond pulsed laser light with a laser energy of 10 µJ/pulse or more using a solid-state laser as a light source;*

(b) *stretching the pulse width of the femtosecond pulsed laser light for hologram recording;*

(c) *dividing the stretched pulsed light from said laser into two beams (Bl, B2); and*

(d) *converging the two beams (Bl, B2) on a surface of a non-photosensitive workpiece (Sl) or within the non-photosensitive workpiece (Sl) for recording a hologram in such a manner that the respective converged spots of the two beams (Bl, B2) are matched with one another to create the interference therebetween so as to record a surface-relief hologram on the surface of the non-photosensitive workpiece (Sl) or an embedded hologram within the non-photosensitive workpiece (Sl) in an irreversible manner;*

(e1) *wherein the stretching step comprises: chirping the wavelength of the femtosecond pulsed laser light and adjusting a pulse-width compression optical circuit to stretch a pulse width of the femtosecond pulsed laser light*
(e2) *into a range from greater than 1 picosecond to 10 picoseconds*
(e3) *while maintaining the energy per pulse.*

IX. The relevant arguments of the opponent may be summarised as follows.

(a) Regenerative amplification as mentioned in paragraph [40] of D1 implied the use of the generally known chirped pulse amplification (CPA) technique which involved stretching and chirping of the laser pulses. Further, it was left open in the opposed patent whether the hologram was recorded by the picosecond pulses or not. The subject-matter of claim 1 of the main request was therefore not novel over D1.

Possible differences between the patent and D1 could in any case only concern the light entering the system, since Figure 1 of the patent was identical to Figure 1 of D1.

(b) D1 mentioned in paragraph [22] unwanted effects of the non-linear property of the material and suggested to either change the recording material or to reduce the energy density of the recording beams.

The recording material was predefined and could thus not be chosen at will. Paragraph [22] of D1 would thus not incite the skilled person to use a different recording material.

Instead, that paragraph would incite the skilled person to reduce the energy density of the individual laser pulses.
There were only two possibilities to do so, namely, to either reduce the peak energy of the laser pulses used to record the holograms or to increase the width of these pulses. Changing the peak energy

of a laser would change the parameters of the laser, such as the temperature. Such a change would therefore require an adaptation of the overall system and was a very delicate task. Thereby, the skilled person would refrain from reducing the peak energy.
On the other hand, adapting the width of the laser pulses using CPA circuitry was a straightforward task, as evidenced by Figure 1 of D8 and Example 3 on page 19 of D9. The skilled person would therefore choose to increase the width of the individual recording laser pulses rather than to reduce the peak energy of these pulses in order to reduce their energy density.
D1 disclosed a pulse width range of up to 900 femtoseconds. The range defined in the opposed patent started at 1 picosecond and thereby directly above the range disclosed in D1. By increasing the pulse width of the pulses defined in D1, the skilled person would thereby arrive at pulse widths in the range defined in the opposed patent.
Thus, the subject-matter of the independent claim of the main request was not inventive.

(c) D4 might explain that using chirped pulses for hologram recording was advantageous. Since D4 was late published, however, its teaching was not available at the relevant time. The only relevant issue was that D1 alone already suggested to use CPA circuitry for increasing the pulse width, whereby the skilled person would automatically arrive at chirped pulses and thus at the invention.

X. The relevant arguments of the proprietor may be summarised as follows.

(a) CPA was generally known at the priority date of the opposed patent. However, regenerative amplification did not inevitably require the use of CPA. D1 thus did not disclose CPA and therefore no stretching and chirping of pulses.
Further, the patent clearly required that the holograms were recorded using chirped picosecond pulses. D1 disclosed recording holograms using unchirped femtosecond pulses.
The subject-matter of claim 1 of the main request was thus novel over D1.

(b) In paragraph [22], document D1 explicitly suggested two possibilities to mitigate unwanted effects of the non-linear property of the recording material.

One of these possibilities was to use a material with a lower non-linear property. The other one was to reduce the energy density of the recording pulses.

Further, the second one of these two possibilities (reduction of the energy density of the recording pulses) could be implemented by a plurality of different measures, such as increasing the beam cross section, lowering the peak energy of the pulses or distributing the total energy of the pulses over a longer time.
In addition, distributing the energy over a longer time would not necessarily require to increase the width of the individual pulses. Instead, the repetition rate of the pulses could be reduced.

In view of this multitude of different possibilities to mitigate unwanted effects of the non-linear property of the recording material, the skilled person would have no reason to choose the particular option of increasing the pulse width of the individual laser pulses.

On the contrary, starting from D1, the skilled person would be dissuaded from increasing the pulse width of the individual recording pulses because D1 suggested to use laser pulses at their Fourier limit, i.e. pulses that are as short as possible for a given spectral bandwidth.

(c) Nothing in D1 indicated that chirped laser pulses were suitable to record holograms. Starting from that document, the skilled person would thus not consider to use chirped pulses for that purpose. The presence of chirp in the pulses was however an advantage when recording holograms. This physical effect was explained in late published D4 (see the right-hand column of page 1138).

Reasons for the Decision

1. The appeal is admissible.

2. The opposed patent

The opposed patent relates to a method of producing holograms in non-photosensitive materials by means of a pulsed laser. The high energies required for that purpose increase the non-linear interactions of the laser beam in with air and with the hologram-recording material. The opposed patent aims at enabling recording holograms in a stable manner despite that increase, in particular (with)in the hologram-recording material (see paragraphs [3] and [4] of the B1-publication).

3. D1

Document D1 also relates to a method of producing holograms in non-photosensitive materials by means of a pulsed laser and is cited in paragraph [11] of the opposed patent. Non-linear interactions between the laser beam and the substrate or recording material are explicitly mentioned in paragraph [22].
The proprietor of the opposed patent is also the applicant of D1. Three of the inventors of D1 are also named as inventors of the opposed patent.

4. Chirped Pulse Amplification (CPA)

Chirped pulse amplification or CPA is a method of amplifying short laser pulses. Standard CPA involves three steps.
The first step is stretching the initial (or seed) pulses by chirping. The total energy of each stretched pulse is the same as the total energy of the corresponding initial pulse. Due to the longer pulse length, however, the peak energy of the stretched pulses is reduced.
The second step is an amplification of the stretched pulses.
The third step is a recompression of the amplified pulses to their original length. The peak energy is raised and is higher than before the stretching step.

The purpose of CPA is to enable the use of (solid) materials in the amplification step which would not withstand (and thus could not be used) at higher peak energies.

5. Main request, Article 123(2) EPC

The Opposition Division came to the conclusion that the present main request (corresponding to the auxiliary request of the first instance opposition proceedings) meets the requirements of Article 123(2) EPC (see point 2.1 and the corresponding sub-points of the contested decision).
There were no submissions of the opponent with respect to this issue during the appeal proceedings.

The last sentence of paragraph [26] of the published application indicates that "... *it is preferable to set the pulse width τ in the range of greater than 1 picosecond to 10 picoseconds*.". This sentence thus provides a basis for the pulse width range defined in feature (e2). The Board therefore sees no reason to diverge from the conclusion of the Opposition Division with respect to Article 123(2) EPC.

6. Claim 1 of the main request, novelty

6.1 Document D1

It was undisputed that D1 discloses, in the terms of claim 1 of the main request (see generally claim 1 and Figure 1 of D1):

A method of producing a hologram in a non-photosensitive material through a two-beam laser interfering exposure process, said method comprising:

(a) emitting a coherent femtosecond pulsed laser light with a laser energy of 10 µJ/pulse or more using a solid-state laser as a light source (see also paragraph [40] of D1);

(c') dividing the pulsed light from said laser into two beams; and

(d') converging the two beams on a surface of a non-photosensitive workpiece or within the non-photosensitive workpiece for recording a hologram in such a manner that the respective converged spots of the two beams are matched with one another to create the interference therebetween so as to record a surface-relief hologram on the surface of the non-photosensitve workpiece or an embedded hologram within the non-photosensitive workpiece in an irreversible manner.

6.2 Distinguishing features (see sections IX.(a) and X.(a) above)

D1 discloses a regenerative amplification titanium-sapphire laser (see paragraph [40]) as acknowledged by both parties.
The expression *regenerative amplification per se* only refers to a particular manner of amplification of laser pulses involving multiple passes through an amplification medium. Regenerative amplification thus does not necessarily imply the use of CPA techniques, contrary to the arguments of the opponent.
Consequently, D1 does not directly and unambiguously

disclose CPA and therefore the features of stretching and chirping the laser pulses, as pointed out by the proprietor.

In addition, *the* two beams defined in feature (d) of claim 1 of the main request refer to the beams created according to feature (c) by dividing the *stretched* and thus *chirped* pulsed light.
That is, contrary to the argument of the opponent, claim 1 directly and unambiguously requires that *chirped picosecond* light in the range defined in distinguishing feature (e2) is used to record the hologram, as submitted by the proprietor.
In contrast to that, *femtosecond* pulses are used in D1 to record the hologram (see features (c') and (d') as defined above).

For the reasons set out above, the subject-matter of claim 1 differs from D1 by the features of

(b) stretching the pulse width of the femtosecond pulsed laser light for hologram recording

(e1) wherein the stretching step comprises chirping the wavelength of the femtosecond pulsed laser light and adjusting a pulse-width compression optical circuit to stretch a pulse width of the femtosecond pulsed laser light

(e2) into a range from greater than 1 picosecond to 10 picoseconds

(e3) while maintaining the energy per pulse,

and in that

- the beams defined in features (c)/(c') and (d)/(d') used to record the hologram are *chirped* and their pulse widths are in the *picosecond* range defined in feature (e2).

The Board notes that all differentiating features identified above concern the nature of the light entering the aperture A1, shown in the lower left corner of Figure 1 of both the opposed patent and D1, as pointed out by the opponent.

6.3 Conclusion with respect to novelty

It follows from the above that the subject-matter of claim 1 of the main request is novel over D1 according to Article 54 EPC 1973.

7. Claim 1 of the main request, inventive step

7.1 CPA, differentiating features (b), (e1) and (e3) (see sections IX.(a) and X.(a) above)

As mentioned above, D1 does not directly and unambiguously disclose the use of CPA to generate the light entering the aperture. However, both parties concurred that CPA was generally known well before the priority date of the patent opposed.
CPA was first used in the mid-1980s and was quickly regarded as a groundbreaking invention in the field of laser physics; its inventors were awarded the Nobel Prize in Physics 2018. In particular with respect to regenerative amplification of femtosecond laser pulses in titanium-sapphire lasers, CPA has to be considered to be a standard technique, see D8 (page 368, right-hand column) and D10 (page 10, first paragraph).

The Board thereby agrees with the parties with respect to CPA.

It follows therefrom that the skilled person, starting from D1 and taking into account their common general knowledge, would have readily used CPA in order to obtain 100 fs pulses by means of a regenerative amplification titanium-sapphire laser as described in paragraph [40] of D1 without the exercise of an inventive step.

As mentioned above, standard CPA involves stretching the pulses of a seed laser by chirping, amplifying the stretched pulses and recompressing the amplified pulses.
Consequently, when using CPA to create the 100 femtosecond pulses disclosed in D1 as argued above, the skilled person would have stretched the pulse width of the femtosecond pulsed laser light for hologram recording according to feature (b).
Further, the step of stretching comprises chirping the wavelength of the femtosecond pulsed laser light and adjusting pulse-width stretching and compression optical circuits to stretch a pulse width of the femtosecond pulsed laser light while maintaining the energy per pulse according to features (e1) and (e3).

It follows from the above that by using CPA for creating the femtosecond pulses disclosed in D1, the skilled person would have included features (b), (e1) and (e3) into the system and method of D1 without the exercise of an inventive step.

The Board notes that this finding corresponds to the finding of the Opposition Division under point 2.2.2.2 of the contested decision.

7.2 Chirped picosecond pulses for recording a hologram (see sections XI.(b), (c) and X.(b), (c) above)

7.2.1 Remaining distinguishing features

If the system and method of D1 were adapted such that the regenerative amplification disclosed in paragraph [40] of D1 was implemented using CPA as argued above, the subject-matter of claim 1 of the main request would still differ from such an adapted system and method by

- feature (e2)

and by

- the use of chirped picosecond pulses in the range defined by that feature for recording the hologram according to features (c) and (d).

7.2.2 Technical effect / objective technical problem to be solved

The technical effect of these remaining distinguishing features is that the energy peak value of the laser pulses is reduced.
This solves the objective technical problem of reducing the unwanted effect of the non-linear interaction of the beams with the hologram-recording material und thus ultimately enables stable recording of a hologram embedded in the hologram-recording material (see for example paragraph [15] of the opposed patent).

7.2.3 The teaching of D1

D1 refers to that issue in paragraph [22]: "...*the coherence of the femtosecond pulse is degraded during the propagation of the pulse through the substrate due to the nonlinear property of the substrate*.".
To overcome this problem, D1 suggests in the same paragraph to either

(a) use a recording material with a lower linear property, or to

(b) reduce the energy density as low as possible,

as submitted by both parties.

Starting from D1, the skilled person would thus have followed these two suggestions to solve the objective technical problem as defined above. However, D1 does not give any details as to how these two suggestions could be implemented in practice.

(a) Selecting the recording material

Whether the first suggestion to select a holographic recording material with a lower non-linear property is an option or not will depend on the purpose for which the hologram is to be used. Thus, the skilled person would have considered this option starting from D1 under certain circumstances, depending on the material that was to be used for the particular hologram in question.

The skilled person would however have been aware that a particular choice of the recording material was not possible in all cases as submitted by the opponent. They would therefore also have explored the second suggestion made in paragraph [22] of D1, i.e. to reduce the energy density as low as possible.

(b) Reducing the energy density

The energy density as defined in D1 (see paragraph [11]: *an energy density of 1 TW/cm²*) could be reduced by a number of different measures, as pointed out by the proprietor.

(i) Increasing the beam cross section

For example, the energy density could be reduced by increasing the beam cross section of the pulses as submitted by the proprietor (see also page 8, last paragraph of the contested decision).
However, such an increase of the beam cross section, similar to the selection of a particular recording material, would be possible only under certain circumstances depending on the hologram to be recorded. The skilled person would thus have explored further possibilities to reduce the energy density.

(ii) Lowering the peak energy

The energy density of the individual laser pulses could also be reduced by lowering the peak energy of the pulses.
The Board accepts that changing the peak energy of the pulses of a laser will influence other parameters of the laser as well, such as the temperature, as argued by the opponent.
However, whenever *any* one of the operating parameters of a laser is changed, the other parameters of the laser will be influenced. That

is, in the present case, the skilled person would have had to take that influence into account irrespective of which option was chosen to reduce the unwanted effects of the non-linear property of the recording material.

In addition, the Board notes that the total pulse energies mentioned in the examples of D1 vary from 1,5 mJ/pulse in Example 5 to 40 μJ/pulse in Example 7, while nothing in these examples suggests a varying pulse width. The skilled person would thus learn from the examples of D1 that changing the peak energy of the pulses can be done without undue burden.

The Board thus does not accept that changing the peak energy of the pulses would be delicate to such an extent such that the skilled person would refrain from using this option when aiming at reducing the energy density of the laser pulses used to record the holograms, contrary to the argument of the opponent.

Further, the Board holds that the argument of the Opposition Division that a reduction of the peak energy would bear the risk that the energy might become too low to write a hologram at all (contested decision, page 9, fourth paragraph) would apply in a similar manner to a stretching of pulses where the total energy of the pulses is distributed over a larger volume of the recording material (normally resulting in a thicker hologram). This risk would thus not dissuade the skilled person from reducing the peak energy when aiming at reducing the energy density.

The Board is thus not aware of anything that would dissuade the skilled person from reducing the peak energy of the individual pulses when trying to reduce their energy density.

(iii) Distributing the pulse energy over a longer time

Finally, the energy density could also be reduced by distributing the energy of the laser pulses used for recording over a longer time, as submitted by the proprietor.

However, when considering to increase that time, the skilled person would have refrained from reducing the repetition rate of the pulses contrary to the argument of the proprietor, since the holograms according to D1 are recorded by a *single* pulse of the laser beam (see paragraph [38] of D1), in accordance with the submissions of the opponent.

The Board accepts the argument of the opponent that the skilled person was aware that a laser pulse could be stretched by means of a CPA arrangement, as evidenced by Figure 1 of D8 and by Example 3 on page 19 of D10.
The skilled person *could* thus have used the CPA circuitry they would have used to implement the regenerative amplifier mentioned in paragraph [40] of D1 (see section 7.1 above) to stretch the femtosecond pulses mentioned therein into the picosecond range.

However, D1 stresses that the laser pulses used for recording the holograms should be generated substantially at the *Fourier transform limit* for

coherence reasons (see paragraph [12]; see also paragraphs [10], [11] and claim 1 of D1), as submitted by the proprietor. That is, the pulses used according to D1 should be as short as possible.
The Board holds that this would have dissuaded the skilled person, starting from D1, from increasing the width of the individual laser pulses beyond the range indicated in D1 into the range defined by feature (e2), as submitted by the proprietor.

In addition, D1 does not contain any hint that chirped pulses could be used for recording holograms, as pointed out by the proprietor. Further, this does not seem to have been part of the common general knowledge, either.
Thereby, even if the skilled person had considered, in view of paragraph [22] of D1, to increase the width of the individual laser pulses to reduce the energy density of these pulses, they would not have additionally chirped the pulses. This would have, in the absence of any further teaching, dissuaded the skilled person from using CPA circuitry for that purpose, contrary to the argument of the opponent.

The Board notes that the teaching of D4 might have incited the skilled person to use chirped light created by CPA for recording holograms. However, the publication date of D4 (5 August 2002) is after the effective priority date of the opposed patent (13 February 2002), as acknowledged by both parties. The skilled person was thus not aware of the teaching of D4 at the relevant date, as submitted by the opponent.

7.3 Summary with respect to inventive step of claim 1 of the main request

For the reasons set out above, the Board comes to the conclusion that the skilled person, when reading D1, would have used CPA for implementing the regenerative amplifier disclosed in D1 to obtain laser pulses with a width of 100 femtoseconds to record holograms. Starting from D1, the skilled person would further have tried to solve the objective technical problem of reducing unwanted effects of the non-linear property of the recording material to thereby enable stable hologram recording.

To solve that problem, the skilled person would have considered to select a recording material with a low non-linear property or to increase the beam cross section, provided that the requirements applying to the hologram to be recorded permitted these options.

The skilled person would further have considered to reduce the energy density of the laser pulses to solve the objective technical problem as defined above.

When doing so, they would have considered to reduce the peak energy of these pulses.

However, they would *not* have considered to increase the pulse width of the individual laser pulse above the limit of 900 femtoseconds indicated in D1, because they would have been dissuaded therefrom by the teaching of D1 that it was preferable to use pulses at the Fourier limit. Starting from D1 and without any additional particular teaching, the skilled person would also have had no reason to assume that *chirped* laser pulses were suitable to record holograms and would thus not have considered using such pulses.

That is, starting from D1 and using their common general knowledge, the skilled person would not have used *chirped picosecond pulses in the range indicated by feature (e2)* for recording holograms.

The skilled person would thus not have arrived at the subject-matter of claim 1 of the main request starting from D1 and using their common general knowledge without the exercise of an inventive step within the meaning of Article 56 EPC 1973.

8. Conclusion

The main request complies with the requirements of Article 123(2) EPC. The subject-matter of independent claim 1 of the main request is new and involves an inventive step in view of D1 and the common general knowledge of the skilled person. No other objections have been substantiated/discussed during the opposition and appeal proceedings.

Consequently, the Board comes to the conclusion that, taking into consideration the amendments made by the proprietor during the opposition proceedings, the patent and the invention to which it relates meet, in the form of the main request, the requirements of the EPC according to Article 101(3)(a) EPC.

It follows from the above that the contested decision must be set aside.

9. Obvious error

The Board notes that the B1-publication of the patent as granted contains an obvious error in paragraph [0036] of the description relating to Example 1. Instead of a "pulse energy of "50 pJ/pulse", a pulse energy of "50 µJ/pulse" should have been defined in that paragraph, in line with the description as annexed to the communication under Rule 71(3) EPC dated 14 July 2011.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of first instance with the order to maintain the patent as amended in the following version:

   Claims: Nos. 1 to 7 according to the main request filed with the statement setting out the grounds of appeal;

   Description: as in the patent specification; and

   Drawings: as in the patent specification.

The Registrar: The Chairman:

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated