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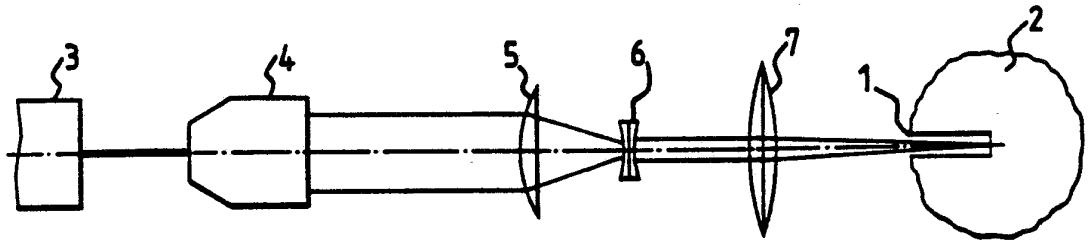
(54) Title: MAKING AN ELONGATE CUT USING HIGH ENERGY RADIATION



(57) Abstract

To make an elongate cut (1) in a diamond (2) using a laser radiation, a cylindrical optical system (5, 6) is used which converges the radiation at a greater angle of convergence in the plane of the cut (1) than in the transverse plane. In this way, the focal spot energy density is increased and cutting at depth is made more effective.

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MAKING AN ELONGATE CUT USING HIGH ENERGY RADIATION

Background of the Invention

The present invention relates to making an elongate cut using high energy radiation focussed to a focal spot in the cut, the radiation usually being a laser beam. A blind groove or hole may be formed in the workpiece, or the workpiece may be cut or pierced right through. The invention has general applicability and in general terms, unnecessary material removal must be avoided as this slows down the cutting process; however, the invention is particularly applicable to gemstones, where it is specially important to avoid unnecessary material removal, and it is also necessary to avoid applying excessive thermal stress; in addition, a particular problem with gemstones such as diamond is that usually only a small percentage of the radiation may be absorbed, so it is important that coupling of the energy to the workpiece be as effective as possible.

In gemstones, the laser cutting can be referred to as forming a kerf (a groove, either for cleaving or for

later sawing), or sawing (cutting right through). In other applications using jewels or gemstones, a blind hole or a through-hole may be formed in order to employ the stone as a bearing.

When sawing gemstones, normal practice is to form a V-section, which should be as narrow as possible to reduce weight loss. There is automatic machinery (work handling) for benching out the V-shape (i.e. scanning the area formed by the length and width of the cut) and for refocussing the beam as the cut depth increases.

A fundamental problem is that the energy density in the focal spot should be as great as possible, but a smaller focal spot (and thus higher energy density) can only be obtained by increasing the cone angle of the focussed beam (i.e. higher numerical aperture). The machined V-section has then to be wider, otherwise the laser energy focussed into the cut is apertured (vignetted) at the entrance to the cut as the depth increases.

The Invention

In accordance with the invention, a system is used which converges the radiation at a substantially greater angle of convergence in the plane in which the cut lies than in the plane transverse to the cut.

Using the invention, the energy density of the focal spot can be increased without widening the machined V-section, as the uninterrupted access provided longitudinally of the cut is utilised. Consequently the angle of the V-section may be reduced and rate of propagation of the cut increased.

Using the invention, the amount of laser energy entering the cut can be increased by cylindrically compressing a spherically expanded beam in the transverse direction. This allows the use of higher spherical beam expansion ratios than is possible without use of the invention because the effect of vignetting by the cut opening is reduced.

The numerical aperture of the optical system is higher in the longitudinal direction than in the transverse direction. The focii must be at the same depth in each plane (transverse and longitudinal). The focal spot (as seen on the flat bottom of the cut) will be an ellipse with its major axis transverse of the longitudinal direction of the cut. The size of the focal spot in the major axis (transverse) direction will be larger than that without using the invention. The full advantage of the invention cannot be observed unless the spherical beam expansion coefficient is increased, so that the focal spot area is reduced without a proportional reduction in the energy entering the cut. The beam can

be expanded and then focused in both planes in order to achieve a sufficiently high focal spot energy density.

If the numerical aperture were to be increased by the same factor in both planes (transverse and longitudinal), as would be the case with a conventional beam expander, any increase in energy density resulting from a reduction in focal spot area, will be at least partially offset by a reduction in energy entering the cut, due to vignetting at the opening, as cutting progresses.

In practice, the ratio of convergence angles (included angle) of the transverse to longitudinal directions can be any value less than unity but the preferred values are from 0.5 to 0.25. In order to achieve this cylindrical optics may be used, preferably with a beam compressor or beam expander having cylindrical lenses.

The Drawing

The invention will be further described, by way of example, with reference to the accompanying drawing, in which:-

Figure 1 is a schematic view, showing the optical system and a stone being cut, in section transversely to the cut; and

Figure 2 is a schematic view of the optical system, as seen in section normal to that of Figure 1.

A cut 1 is being formed in a diamond 2. The optical system includes a laser 3, a spherical beam expander 4, a beam contractor formed by two lenses 5,6, and a focussing lens 7. The lenses 5,6 are cylindrical lenses, forming a beam compressor for contracting the beam in the plane of Figure 1 but not in the plane of Figure 2. In this way, the angle of convergence is substantially greater in the plane longitudinally of the cut (Figure 2) than in the plane transversely of the cut (Figure 1). The focussing lens 7 can be a conventional spherical lens. The laser 3 can be a high-power Q-switched YAG laser in fundamental TEM_{oo} mode - the beam has a Gaussian distribution and produces a very small focal spot.

In practice, magnification values of 10 to 20x have been used for the beam expander 4 and 0.25 to 0.5x for the beam contractor 5,6. If the width of the beam between the laser 3 and the beam expander 4 is $\underline{w}$, it is typically $3\underline{w}$ - $5\underline{w}$ between the lenses 6,7 in Figure 1 and $10\underline{w}$ - $20\underline{w}$ between the lenses 6,7 in Figure 2.

The present invention has been described above purely by way of example, and modifications can be made within the spirit of the invention.

Claims

1. A method of making an elongate cut using high energy radiation focussed to a focal spot in the cut, wherein a system is used which converges the radiation at a substantially greater angle of convergence in the plane in which the cut lies than in the plane transverse to the cut.

2. The method of Claim 1, wherein a beam of the radiation is spherically expanded and is then cylindrically compressed in the plane transverse to the cut.

3. Apparatus for making an elongate cut using high energy radiation focussed to a focal spot in the cut, comprising a system which converges the radiation at a substantially greater angle of convergence in the plane in which the cut lies than in the plane transverse to the cut.

4. The apparatus of Claim 3, wherein said system comprises a spherical beam expander for expanding a beam of the radiation in both said planes, followed by a cylindrical beam compressor for compressing the beam in the plane transverse to the cut.

5. A method of making an elongate cut, substantially as herein described with reference to the accompanying drawing.

6. Apparatus for making an elongate cut, substantially as herein described with reference to, and as shown in, the accompanying drawing.

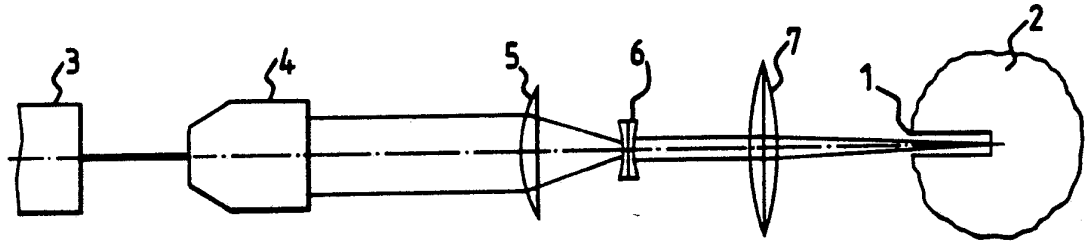

FIG.1.

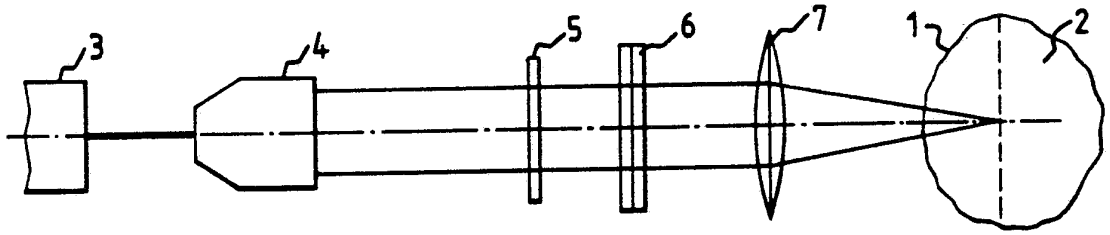

FIG.2.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 89/00942

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 B23K26/06

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	B23K

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	IBM TECHNICAL DISCLOSURE BULLETIN. vol. 14, no. 9, February 1972, NEW YORK US pages 2641 - 2642; M.A. GRIMM: "Optical system for laser machining of narrow slots" see the whole document	1-6
X	DE,A,1565144 (TELELEFUNKEN PATENTVERWERTUNGSGESELLSCHAFT MBH) 24 July 1969 see page 2, paragraph 2 - page 3, paragraph 1; claim 1; figure 1	1-6

° Special categories of cited documents :[10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
17 NOVEMBER 1989	30. 11. 89
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	ARAN D.D.

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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

PCT/GB 89/00942
SA 30649

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A-1565144	19-02-70	None	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82