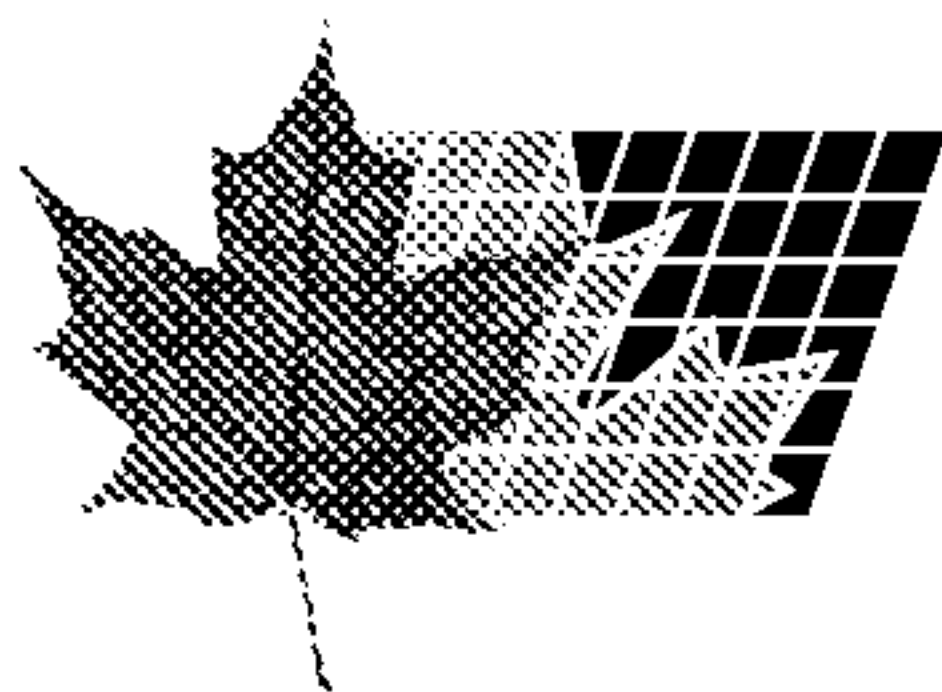
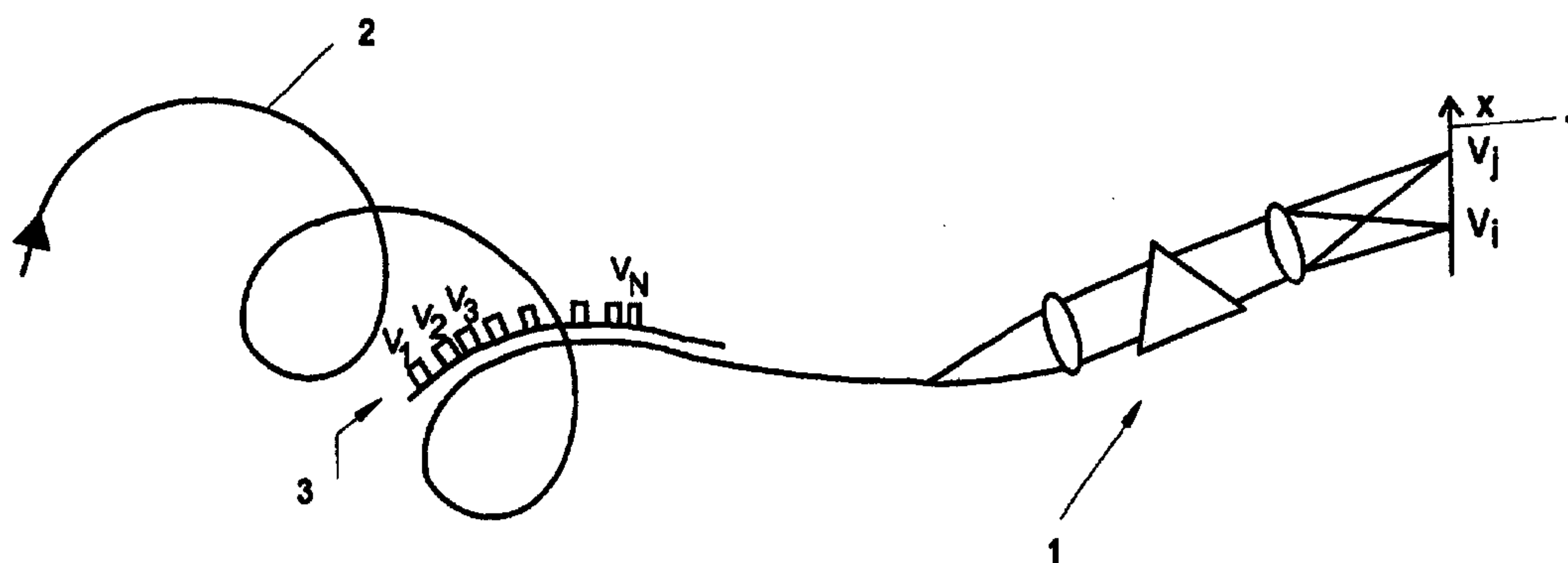




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(54) **SYSTEME DE TRANSMISSION D'INFORMATIONS AVEC DES
COMPOSANTS OPTIQUES REPARTITEURS DE
FREQUENCE POUR TRAITER DES IMPULSIONS OPTIQUES
EN PARALLELE**
(54) **MESSAGE TRANSMISSION SYSTEM WITH FREQUENCY
DIVIDING OPTICAL COMPONENTS FOR PARALLEL
PROCESSING OF OPTICAL PULSES**



(57) L'invention concerne un système optique de transmission d'informations avec des composants optiques répartiteurs de fréquence, où des impulsions lumineuses de différentes fréquences sont conduites par des réseaux cristallins fibreux et/ou des cristaux photoniques hors d'une fibre optique et sont représentées en dehors de la fibre optique. Les réseaux cristallins fibreux pour différentes fréquences peuvent être ordonnés les uns derrière les autres dans une seule période ou dans différentes périodes. Les cristaux photoniques peuvent s'utiliser à l'extrémité de la fibre optique ou être gravés en un canal ou en un creux dans une fibre de verre. Des éléments additionnels de temporisation permettent d'assurer que des impulsions lumineuses de fréquence différente puissent être représentées simultanément dans un rapport temporel prédéterminé et voulu, dans la mesure où il y a un traitement ultérieur parallèle.

(57) The invention relates to a message transmission system with frequency dividing optical components. According to the invention, light pulses with different frequencies are coupled out of an optical fibre by means of fibre grating and/or photoionic crystals and imaged by focusing elements outside of the optical fibre. The fibre grating for different frequencies can be arranged in a single period or in different successive periods. The photoionic crystals can be used at the end of the optical fibre or can be etched into a channel or pit in a glass fibre. Additional delay elements ensure that light pulses with different frequencies are imaged at the same time in a predetermined chosen time ratio, in accordance with a parallel reprocessing stage.



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(21) Internationales Aktenzeichen: PCT/EP98/03085 (22) Internationales Anmeldedatum: 26. Mai 1998 (26.05.98) (30) Prioritätsdaten: 08/882,638 25. Juni 1997 (25.06.97) US (71) Anmelder: DEUTSCHE TELEKOM AG [DE/DE]; Friedrich-Ebert-Allee 140, D-53113 Bonn (DE). (72) Erfinder: DULTZ, Wolfgang; Marienbergerstrasse 39, D-65936 Frankfurt am Main (DE). KOOPS, Hans, Wilfried, Peter; Ernst-Ludwig-Strasse 16, D-64372 Ober-Ramstadt (DE). FRINS, Erna; Garibaldi 2859, Ap. 403, 11600 Montevideo (UY). MELTZ, Gerald; 77 Daventry Hill Road, Daventry, Avon, CT 06001 (US).		(81) Bestimmungsstaaten: CA, JP, NO, europäisches Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Veröffentlicht <i>Mit internationalem Recherchenbericht.</i>
(54) Title: MESSAGE TRANSMISSION SYSTEM WITH FREQUENCY DIVIDING OPTICAL COMPONENTS FOR PARALLEL PROCESSING OF OPTICAL PULSES		
(54) Bezeichnung: NACHRICHTENÜBERTRAGUNGSSYSTEM MIT FREQUENZAUFTEILENDEN OPTISCHEN BAUELEMENTEN ZUR PARALLELVERARBEITUNG OPTISCHER IMPULSE		
(57) Abstract The invention relates to a message transmission system with frequency dividing optical components. According to the invention, light pulses with different frequencies are coupled out of an optical fibre by means of fibre grating and/or photoionic crystals and imaged by focusing elements outside of the optical fibre. The fibre grating for different frequencies can be arranged in a single period or in different successive periods. The photoionic crystals can be used at the end of the optical fibre or can be etched into a channel or pit in a glass fibre. Additional delay elements ensure that light pulses with different frequencies are imaged at the same time in a predetermined chosen time ratio, in accordance with a parallel reprocessing stage.		

FILE, PINTN THIS AMENDED
~~TEXT~~-TRANSLATIONDevice for Transmitting and Processing Optical
Signals of Different Frequencies

5 The present invention relates to a device for
transmitting and processing optical signals of different
frequencies that are passed in series in one and the same optical
fibre.

10 Optical telecommunications are nearly always effected
by transmitting a sequence of individual, binary-coded light
pulses. Since transmission frequencies are today already
advancing into ranges that no longer permit electronic data
processing, and, more particularly, do not permit the complex
15 encoding and decoding that is required for secret communications
there is a pressing need for optical elements that can prepare
chronological bit sequences optically for further parallel
processing. Optical parallel processing can transform a large
quantity of binary or analogue signals arranged as an image or a
20 pattern simultaneously, and thus works considerably faster than a
conventional electronic computer.

 Exceptional time savings can be achieved by using
parallel processing for certain optical operations such as a
Fourier transformation. Since Fourier transmissions are an
25 essential component of machine pattern recognition, it is
precisely the encoding and decryption of messages that could be
effected easily and very quickly in terms of optics. It is

known that electro optical components that read chronological time sequences into spatial areas can be constructed using a Brownian tube type design as a basis.

5 At the present time, as is described in German Patent 196 09 234 C2 (Koops), which is not necessarily the prior art to the present invention but is considered to be an alternative solution, it is only in micro-tubes that the electron beam can be deflected quickly enough to read in signals that are in the
10 multi-Gigahertz range. Another method encodes the individual optical pulses in alternation with the help of light polarization. The first, third, fifth--which is to say every odd-numbered pulse--is polarized vertically, for example, and all even-numbered pulses are polarized horizontally and linearly.
15 Then the even-numbered and the odd-numbered pulses can at least be separated locally in each case with the aid of a polarizing beam splitter. Cascading permits a greater degree of separation. The advantage of this method is that the separating element, i.e., the beam splitter, is purely passive. Once the pulses
20 have been electro-optically polarization-encoded, there is no longer a need for an active switching operation. Obviously, one disadvantage of the method is the small number of only two parallel channels per cascade stage.

 It is the objective of the present invention to
25 describe a device of the type referred to in the introduction

hereto, which permits parallel processing of frequency-coded optical signals that occur in series in an optical fibre. It is intended that the device can be manufactured in a cost effective manner, and it should be simple to install in a small space.

5 This objective has been achieved in that the fibre is provided with structures that divide light according to frequency; these structures separate the optical signals that are passed through the fibre and radiate them to the outside, spatially offset relative to each other, as a function of
10 frequency; and in that the radiated signals are imaged by means of suitable devices for further processing at a location assigned to their particular frequency on a spatial area that is outside the fibre.

 The signals that have been separated and imaged in
15 this way can either be made visible immediately, on a screen that is arranged on the spatial area, or they can be further processed by coupling elements such as an arrangement of the light-receiving ends of optical fibres that are arranged along the spatial area, or with a CCD array.

20 The frequency-dividing structure of the fibre can be designed as a spectrograph, by which the optical pulses can be separated from each other locally and arranged on the spatial area. Particularly suitable for this purpose is, in particular, a prism-based spectrograph, a grating-based spectrograph, or even a
25 two-beam or multi-beam interferometer.

In order to use the present invention, it is essential that the individual, successive optical pulses be frequency-
5 encoded instead of polarization-encoded. Since, on the one hand, the light frequency within an optical telecommunications window can be easily altered by 100 nm and, on the other hand, since semiconductor lasers can be detuned by several nanometers by varying the applied voltage, it is possible, in principle, for
10 different frequencies to be assigned to optical pulses within a broad range. To this end, a plurality of semiconductor lasers having different main frequencies should be electrically switchable with respect to their radiation frequencies. The resulting optical pulses having different frequencies are then
15 binary-encoded for telecommunications purposes and are fed into the transmitting optical fibre. Thus, a sequence of pulses of increasing frequency V_i is impressed upon the communication; of these, the first is of frequency V_1 . It then follows that $V_1 < V_2 < V_3 < \dots < V_i < V_{i+1} < \dots < V_n$.

20 In a first embodiment of the present invention, provision is made such that the fibre itself is formed section by section as a frequency-dividing structure that separates the optical signals according to their frequency and radiates them, offset spatially relative to each other, as a function of
25 frequency.

This results in a very compact construction since the light-conducting areas of the fibre itself act as a functional element and additional structures to produce the structures on the fibre become superfluous.

5 The spatial area can be flat or of another shape in order to achieve a specific effect, for example to correct any distortion of the signals that have been imaged or to correct the image. In addition, the signals that arrive serially and in sequence in the fibre can be time-shifted by curving the spatial
10 area or having it in an inclined position, or by using additional delaying elements, so that the signals can be received at the same time on the spatial area and thereby subjected to further, actual parallel processing.

 Additional advantageous developments and enhancements
15 of the present invention are made possible by the measures set out in the secondary claims.

 The present invention will be described in greater detail below on the basis of embodiments shown in the drawings appended hereto. These drawings show the following:

- 20 Figure 1: the use of a passive optical component to divide light at the extremities of an optical fibre;
- Figure 2: use of diagonally arranged fibre gratings to couple the light out of the optical fibre;
- Figure 3: the use of another diagonally arranged fibre grating to
25 couple the light out of the optical fibre;

Figure 4: a spiral arrangement of fibre gratings;

Figure 5: use of photonic crystals etched into an optical fibre
for frequency division of light;

Figure 6: the delay that occurs between two optical pulses of
different frequencies;

Figure 7: the use of a delay element for ensuring simultaneous
imaging of the light pulses on a matrix.

In the drawings, identical components bear identical
reference numbers.

In the drawings, structures manufactured by micro
technologies as parts of optical fibres are symbolized by
diagrammatic representations of the optical elements such as
lenses and prisms that they simulate. In the following,
references is made to sources that describe the micro technical
production of the optical elements that are used in greater
detail. As a rule, the optical effect of the micro structures is
comparable to that of lenses, prisms, and the like. For this
reason, the elements that are used are referred to by such
designations in the following text.

The present invention uses a passive, optical structure
that divides light that passes through it locally and spectrally,
to separate frequency-coded pulses that are conducted serially
and images them on a spatially arranged area. Figure 1 shows the
use of an optical component 1 for this purpose. In the example,
this is a spectrograph based on a prism that is incorporated into

an optical fibre 2 or at the end thereof, said optical fibre transmitting a frequency coded digital or analogue message 3 as optical pulses that are imaged on a spatially arranged surface 4. Fibre gratings can be used as spectrographs for the spatial
5 division of the frequency-coded light pulses. Such fibre gratings are described in US 5,546,481 (Meltz et al.) for example.

As is shown in Figure 2 and Figure 3, blazed fibre gratings 5 are arranged diagonally in order to direct the light
10 out of the optical fibre. By using suitable focusing elements 6, such as anamorphic lenses as described in German Patent Application No. 196 30 705 A1 (Koops), the beams of one single frequency (colour) can be focused on a spatial area 4. Each frequency V_i has a different focal point. The spatial area 4 can
15 be parallel to fibre 2, curved in space, or can be set at an angle.

With regard to lenses 6, these can also be incorporated directly on the optical fibre. German Patent Application No. 197 13 374 (Koops et.al.) describes a method for manufacturing such
20 lenses. In an optical fibre having a blazed Bragg-fibre grating, a lens can be placed on the cladding of the fibre. The lenses to be used are mounted on the cylindrical fibre cladding surfaces and can be manufactured with the aid of vapour deposition technology, corpuscular beam lithography characterized by a great
25 depth of focus, or with the aid of X-ray lithography using

intensity-modulated masks. The lenses can also be constructed by means of polymerization, i.e., through beam polymerization of monomers absorbed or condensed on the surface, with the aid of the light diffracted out of the fibre. In this context, to
5 define the lens profile, the rate at which material is supplied should be controlled through a slotted mask in order to shape the lens.

The optical fibres 2 shown in Figure 3 incorporate blazed fibre gratings are made up of a plurality of gratings of
10 different periods disposed one after the other in the optical fibre 2. Each grating is positioned to couple light of a single frequency out of the fibre2 and to emit that light. In this manner, in the same way is shown in Figure 2, linear arrays of the individual light pulses can be formed on a spatial area
15 outside the optical fibre 2 by means of focusing elements 6.

Figure 4 shows an optical fibre in which the individual inclined (blazed) fibre gratings 5 are arranged in a spiral form within the optical fibre 2. Because of this, and in conjunction with suitable focusing elements 6 (not shown herein, but
20 understood to be similar to those in the other figures) the pulses can be imaged in rows and columns on the area 4, which in this instance is flat, and along which a projection screen can be arranged. Each spiral turn of the spiral grating group corresponds more or less to one line on which the individual
25 columns are arranged side by side. Adjacent positions in the

rows correspond to gratings that are located directly one behind the other within the fibre 2 with a slightly different osculating plane. Subjacent column positions correspond to gratings, that lie immediately behind each other in the spiral turns. In place of the spiral arrangement of the gratings, the optical fibres themselves can be coiled or twisted (not shown herein), and thereby achieve the same effect of an area light-pulse array.

As is shown in Figure 5, in place of light-generated optical fibre gratings, the frequency-dividing elements can be replaced by photonic crystals 7. Photonic crystals are crystals having lattice constants of a few hundred nanometers and which, in contrast to the fibre gratings described above, comprise far fewer individual elements (grating components), since the differences in their refractive indices are far greater than those of fibre gratings. Moreover, resonance effects enhance their efficiency. Photonic crystals and fabrication of such crystals are discussed in H. Koops, "Photonic crystals built by three-dimensional additive lithography enable integrated optic of high density," SPIE, Vol. 2849/29 (Denver, 1996). As with fibre gratings, the photonic crystals may be fashioned as frequency-selective reflectors, prisms, or beam splitters.

The photonic crystals may be used at the ends of the optical fibres 2 or, as shown in Figure 5, in small channels or trenches 8 etched into the optical fibre 2. A method for fabricating such small channels or trenches 8 in the optical

fibre 2 is described, for example, in DE 197 13 371 (Koops et al.), titled "Wellenlänge-Entkopplung aus D-profil-Fasern mit photonischen Kristallen" [Wavelength Decoupling from D-section Figures with Photonic Crystals]. In this patent, light is
5 conducted in a D-profile fibre immediately beneath the surface of the fibre. A slit that is a few micrometers wide is cut into this fibre surface by lithography and dry etching, or wet-chemical etching, or by means of laser or ion ablation. A photonic crystal is then placed directly in the path of the light
10 by means of additive, three-dimensional lithography and, because of the crystals selective effect on transmitted light, it enables a small portion of the spectrum to be coupled into the fibre or decoupled out of it. This light, which includes a small spectral range, can be decoupled laterally out of the fibre since the
15 photonic crystal media either permit the passage of light or conduct it exclusively inside the material, provided that the light is of a specific wavelength. Because of the special configuration of the crystal, a portion of the spectrum can be reflected out of the fibre at less than 90°. The light can also
20 be inserted into a continuation fibre with the aid of a three-dimensional lens,.

Thus, the photonic crystals diffract the light of frequency ν_i out of the fibre 2 from the channels or trenches. Suitable lattice constants of the photonic crystals 7, situated
25 one behind the other in pits (cutouts) 8 in the optical fibre 2

enable the various frequencies and, thus, light pulses to be coupled out of the fibre 2 and imaged onto an area 4 or coupled into other waveguides or detectors by means of focusing elements.

5 In the example shown in Figure 6 and Figure 7, information is transmitted with the aid of the above described frequency-dividing elements, which is to say with individual sequences of light pulses. Each of these sequences comprises a number of optical pulses that are separated from each other spatially by the frequency-dividing structure (shown here as a shaded area),
10 and projected on to a screen that is arranged along the spatial area 4. As can be clearly seen from Figure 6, the pulses V_i arrive simultaneously on the screen only at certain screen positions and shifted by the time delay Δt . The screen can be tilted or in some circumstances curved so that all the pulses are
15 displayed simultaneously and cyclically through illumination.

Rather than using a tilted or curved screen (or in conjunction with these) a delay can be brought about in that the screen is coated with a fluorescent or phosphorescent substance on which images persist until all pulses of one pulse sequence
20 have arrived. In order to avoid a strong, undesirable persistence, which permits the individual pulse sequences to overlap, electrical or electro optical switching elements must be used in order to separate the individual sequences.

As is shown in Figure 7, the individual pulses can be
25 collected by the ends 11 of optical fibres 9 that are configured

to couple in light and are arranged along the spatial area 4,
when said pulses can be imaged on a matrix 10. Each individual
optical fibre 9 must serve as a delay section (delaying interval)
for the pulses that it collects, so that the pulses of a
5 frequency sequence are imaged simultaneously on the matrix 10.
Detectors are required for further optical processing, these
taking into account the broad-band properties of the pulse
sequence. Other displaying elements can be configured as air
gaps or glass prisms for gradient index prisms.

10 Instead of glass fibres 9, detectors can also be used
directly. Each pulse of one sequence is detected separately, and
the delay until further parallel electronic processing is
effected electronically.

Patent Claims

1. Device for transmitting and processing optical signals of different frequencies that are passed in series in one and the same optical fibre, characterized in that the fibre is provided in that the fibre (2) is provided with structures (1) that divide the light according to frequency, and separate the optical signals (3) that are passed through the fibre and radiate them to the outside, offset to each other as a function of frequency; in that in order that they can be further processed by devices (6) suitable for this purpose, the radiated signals (Vi) are imaged by devices (x) at a point of a spatial area (4) that is located outside the cable and is allocated to their particular frequency.
2. Device as defined in Claim 2, characterized in that the fibre (2) itself is formed section by section as a frequency-dividing structure (1) that separates the optical signals (3) according to their frequency and radiates them offset spatially relative to each other as a function of frequency.
3. Device as defined in Claim 2, characterized in that a projection and/or focusing device (6) is provided to image the radiated signals on the spatial area (4).

4. Device as defined in one of the preceding claims, characterized in that at least one focusing element is provided on the spatial area to accept the signals that are imaged onto the spatial area.
 5. Device as defined in one of the preceding claims, characterized in that there is a focussing element at all the points of the spatial area at which a signal arrives.
 6. Device as defined in one of the preceding claims, characterized in that the focussing elements are located at the extremities (11) of optical fibres that serve to pass on the signals.
 7. Device as defined in one of the preceding claims, characterized in that the signals are imaged at points of the spatial area (4) that are arranged in lines.
 8. Device as defined in one of the preceding claims, characterized in that the shape of the spatial area (4) is so configured that each individual signal (V_i) reaches the spatial area time-shifted by a specific amount as a function of its frequency.
-

9. Device as defined in one of the preceding claims, characterized in that the shape and arrangement of the spatial area is such that the signals arrive simultaneously on the spatial area in cycles.
 10. Device as defined in one of the preceding claims, characterized in that the frequency-dividing structure is formed as a fibre-grating structure (5), the grating elements of which are arranged in the optical fibre either diagonally (blazed) or helically.
 11. Device as defined in one of the preceding claims, characterized in that the frequency-dividing structure is formed in the optical fibre as a photonic crystal structure (7).
 12. Device as defined in one of the preceding claims, characterized in that at least one delay element is provided in order to even out propagation-time differences by delaying the signals coupled out of the fibre over time.
 13. Device as defined in one of the preceding claims, characterized in that the delay element is a phosphorescing/fluorescing substance that evens out
-

propagation-time discrepancies between individual pulses by persistence.

14. Device as defined in Claim 13, characterized in that a projection screen that is coated with the substance is arranged along the spatial area.
15. Device as defined in one of the preceding claims, characterized in that the delay element is an optical fibre (9) of a length that corresponds to the delay that is desired.

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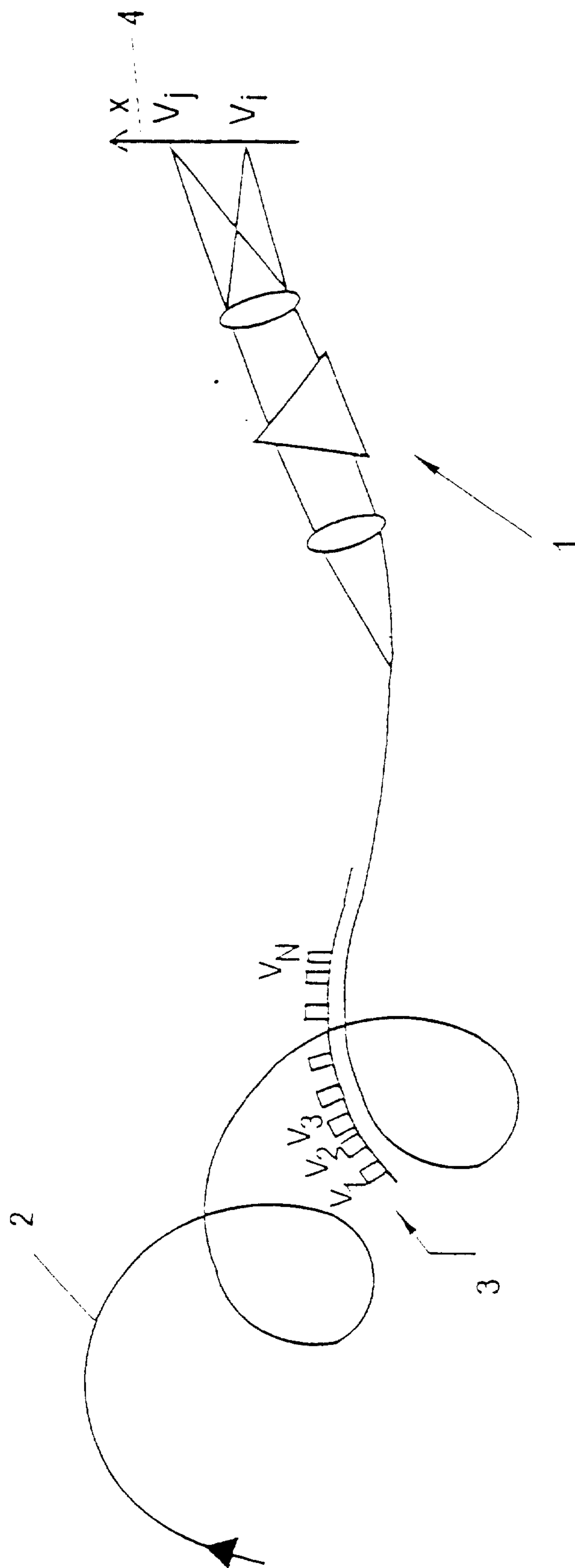


Fig. 1

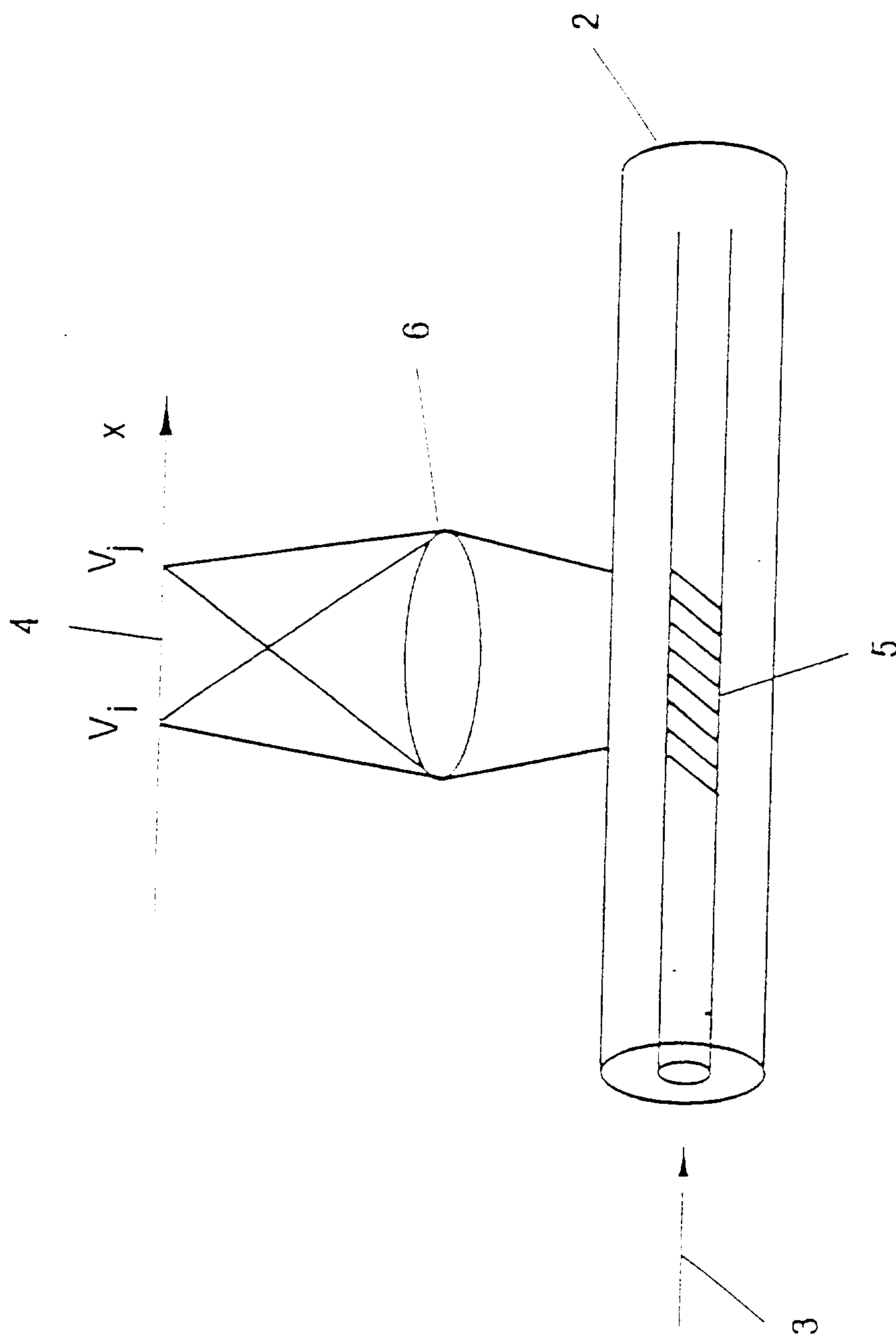


Fig. 2

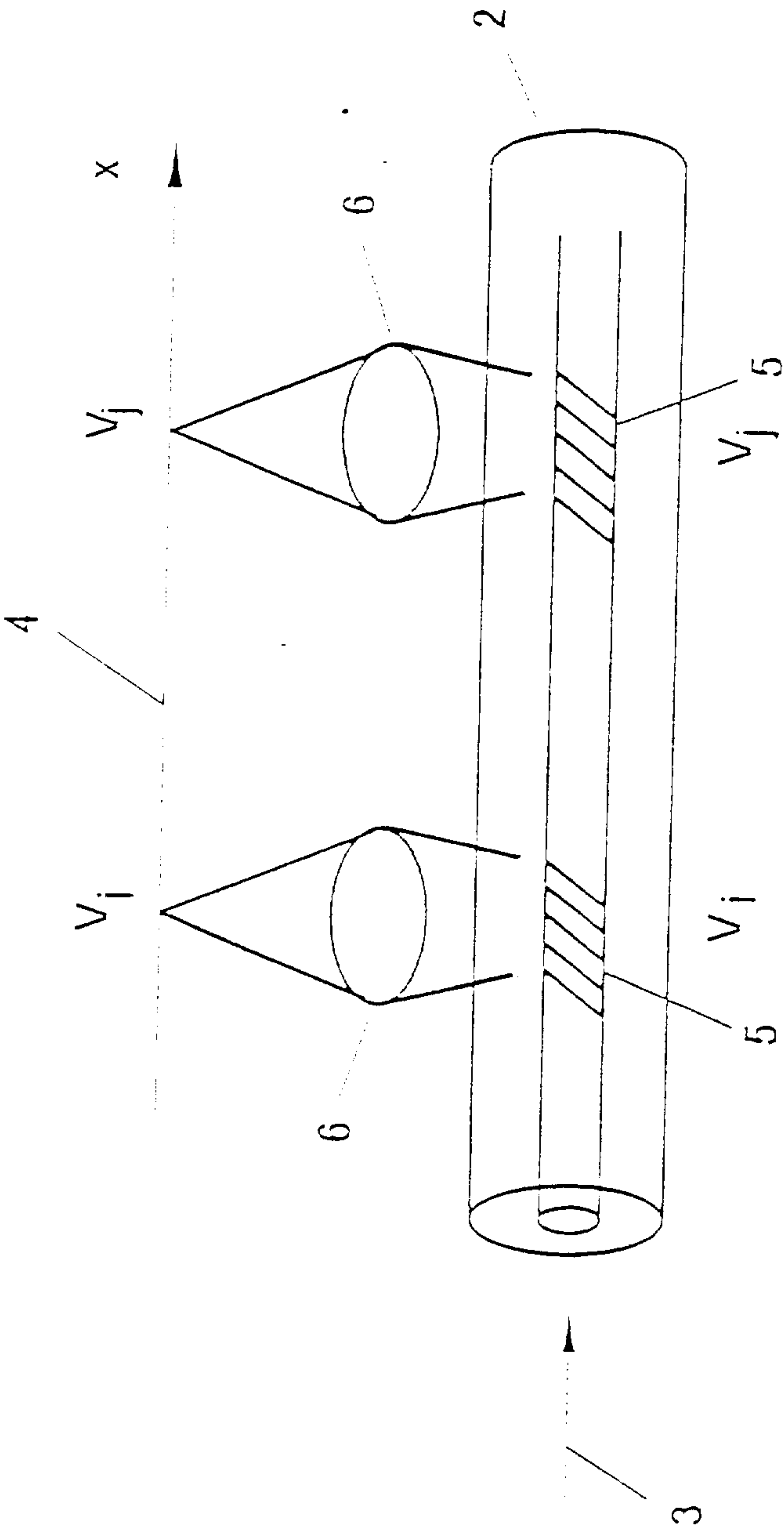


Fig. 3

GERMANY

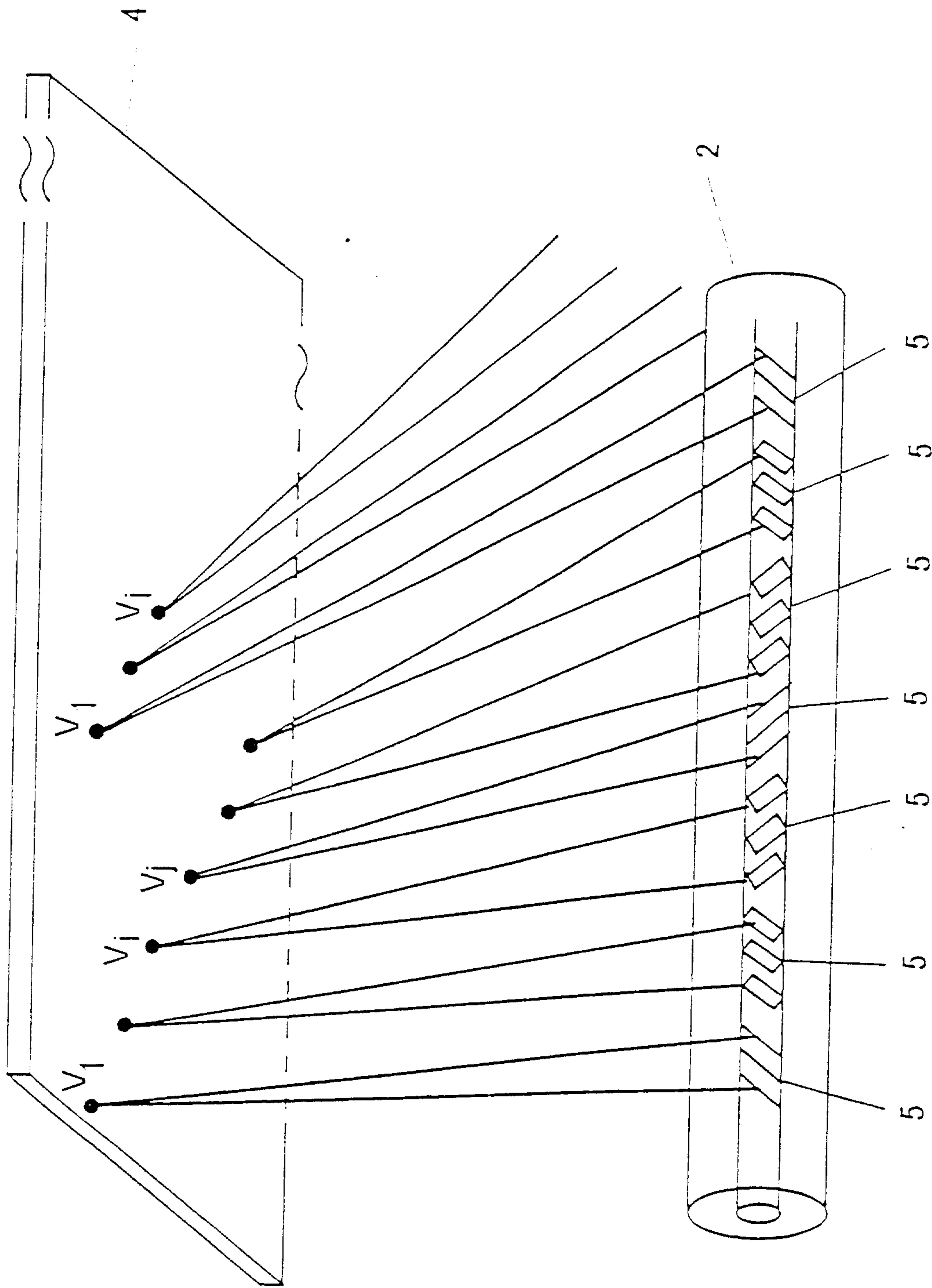


Fig. 4

GEANDREES P. 10/11

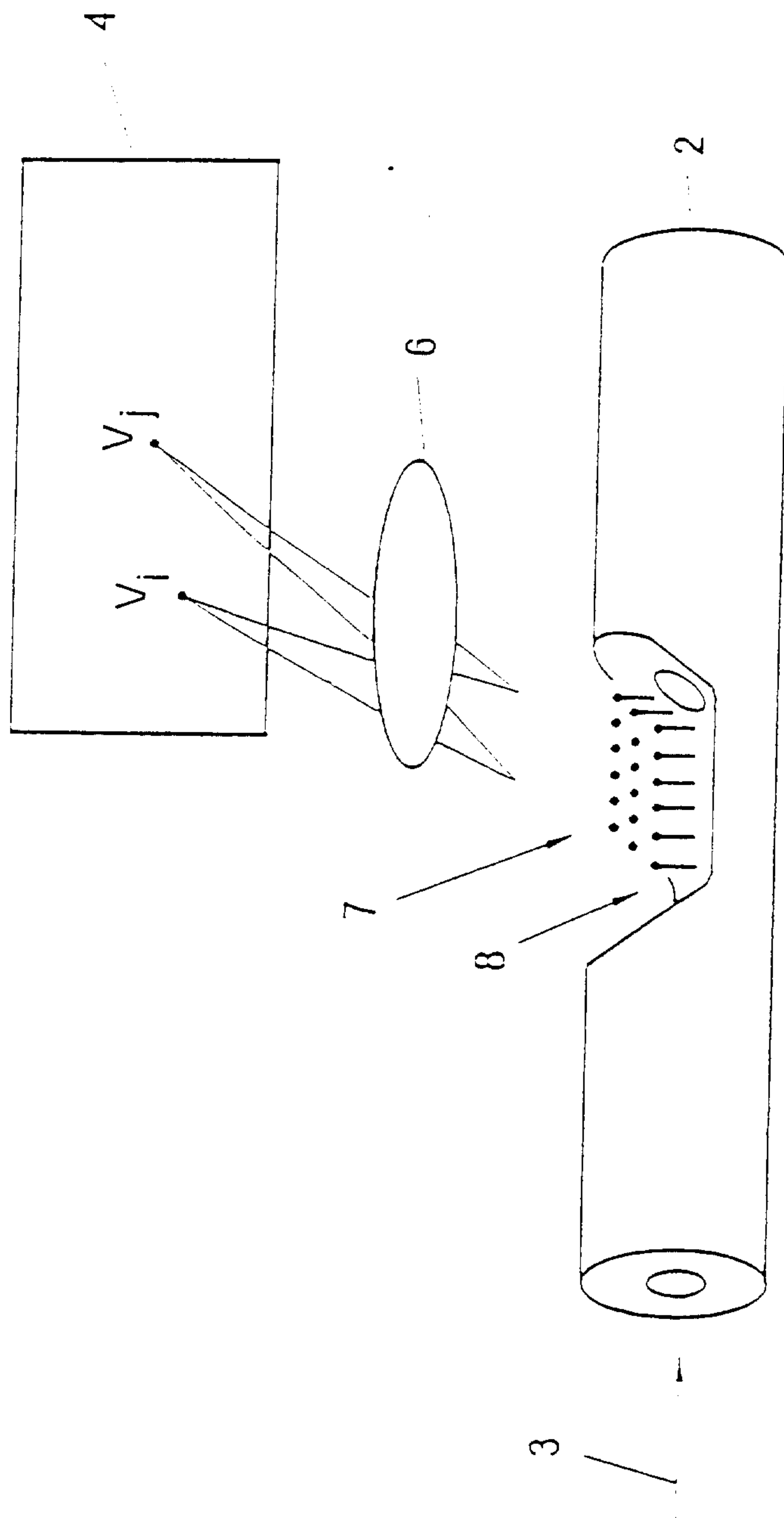


Fig. 5

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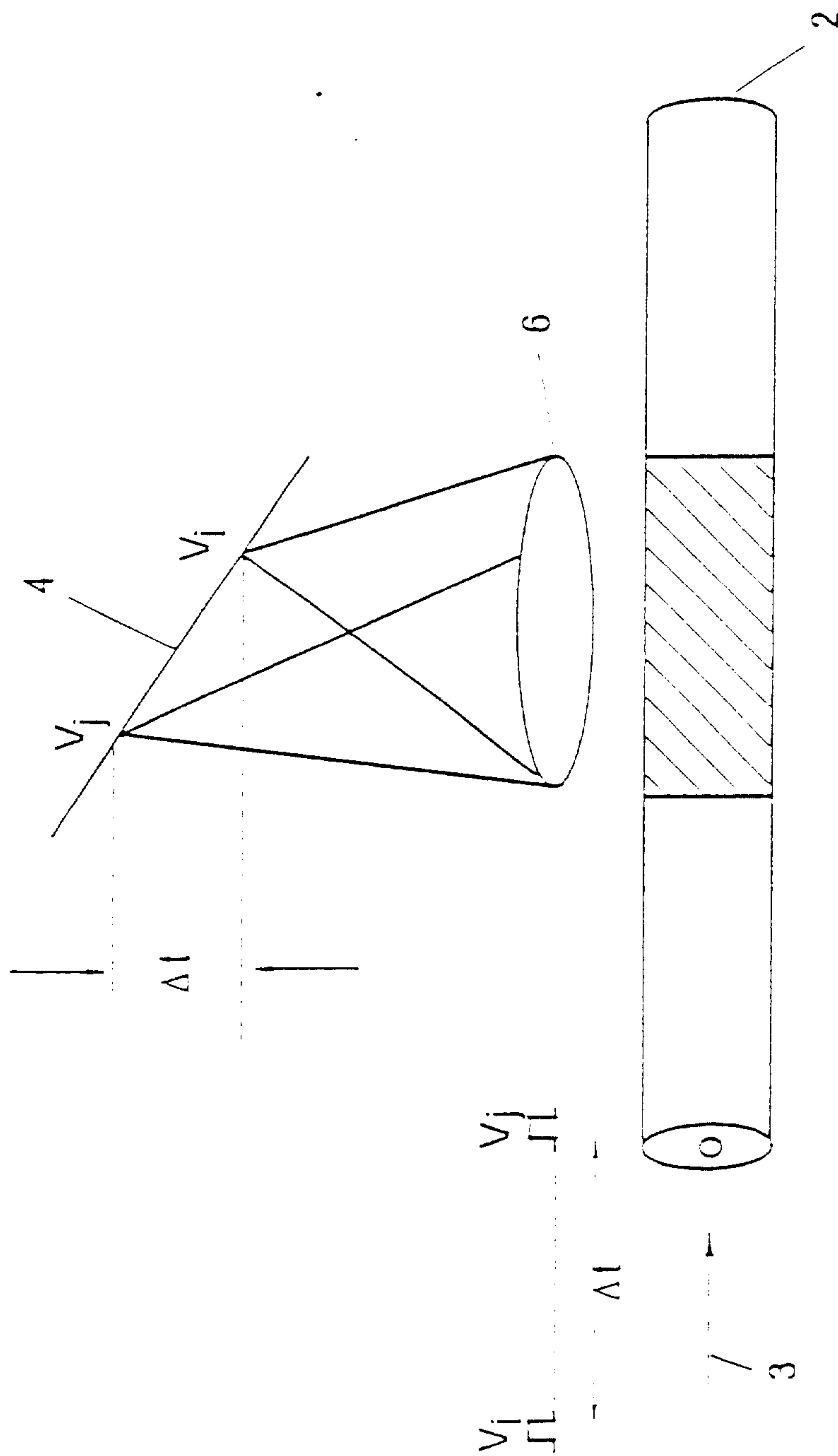


Fig. 6

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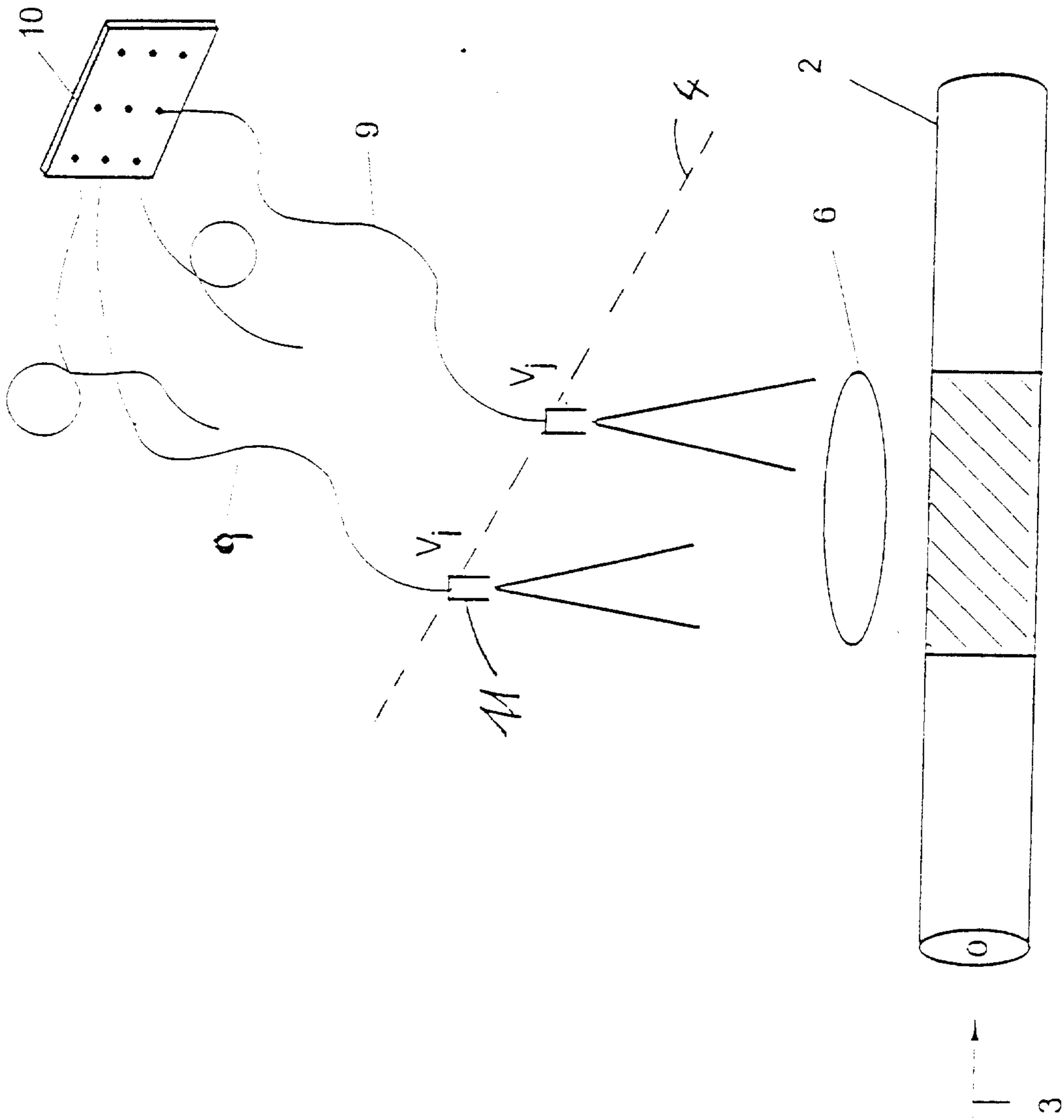


Fig. 7

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