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OPTICAL DEMULTIPLEX TRANSMISSION EQUIPMENT

This invention relates to optical demultiplex transmission equipment of the type comprising several light transmitters for generating several light signals of discrete wave lengths, a dispersion grating, a first
5 light conductor which is directed at the dispersion grating and conducts a multiplex signal formed by superimposition of the light signals of various wave lengths, and several second light conductors which are arranged side-by-side in each case with an input end
10 in the diffraction plane of the dispersion grating for separate decoupling of the individual light signals of the multiplex signal.

In optical communications technology, optical demultiplex equipment with dispersion gratings has proved
15 successful in systems which are used to simultaneously process a large number of light signals of different

wave length. The most favourable features of dispersion gratings is their slight overall size and their slight insertion damping of each transmission channel.

A considerable problem which arises in the use of dispersive grating demultiplex equipment relates to the channel separation. In currently known wavelength multiplex equipment, the wave length difference between adjacent channels, in other words the channel spacing, is fixed at a specific value, for example 30 nm. As a consequence of this, taking into account the geometry which is preset by the construction of the dispersion grating, there must be a specific arrangement of the light conductor fibres intended for decoupling of the individual channels.

Fig. 1 shows an example of conventional demultiplex transmission equipment 10. A dispersion grating is formed as a reflection grating 12 on a spheric side surface of a solid body 11 made from a material which is transparent in the wave length range of the light signals to be transmitted. That side surface 13 of the body 11 which lies opposite the reflection grating 12 stands perpendicular to the diffraction plane of the reflection grating 12. A first light conductor fibre or input conductor fibre 14 has an exit end 15 which is fastened to this surface 13, for example by

being bonded thereto with a transparent adhesive.
This input light conductor fibre 14 conducts a
multiplex signal $\lambda_1 + \lambda_2 + \lambda_3$ etc. ... consisting
of several light signals of different wave lengths
5 ($\lambda_1, \lambda_2, \lambda_3$, etc. ...). The carrier light
waves of these individual light signals are generated
by light transmitters L_1, L_2, L_3 ... etc.

The light transmitters are monochromatic and
they are usually lasers, particularly semiconductor
10 lasers. The multiplex signal $\lambda_1 +$
 $\lambda_2 + \lambda_3$ etc. travels through the transparent body
11 and is diffracted at the side surface formed as the
reflection grating 12 and reversed in its direction.
Since the diffraction angle $\theta_1, \theta_2, \dots$ etc. in each
15 case depends on the respective wave length $\lambda_1, \lambda_2, \dots$
etc. of the light incident on the reflection grating 12,
the diffracted beams impinge as a function of the
respective wave length $\lambda_1, \lambda_2, \dots$ etc. at various
locations on that side 13 of the body 11 which lies
20 opposite to the reflection grating 12. In order to
compensate for the spread of the diffracted light beams
in the body 11, the surface carrying the reflection
grating 12 is convex in design so that the diffracted
beams are bunched or focussed.

25 The spacing of the points of impingement of the

individual light signals of different wave length depends on the individual diffraction angles and on the distance between the reflection grating 12 and the side surface 13 lying opposite it. With a preset
5 channel spacing, the latter distance is so selected that at the points of impingement of the diffracted light beams on the side surface 13 specific output light conductor fibres 16 for decoupling of the individual light signals can be arranged at such a
10 spacing relative to one another that a cross-talk or mixing of adjacent channels is avoided.

Conventionally, these output light conductor fibres 16 are held, in their region butting against the body 11, at the spacings preset by the grating
15 geometry and the channel spacings by means of a precision fixing and guidance mechanism 20. This guidance mechanism 20 has a number of V-shaped grooves corresponding to the number of the output light conductor fibres 16. The V-shaped grooves 21
20 are arranged side-by-side and their spacings are determined by the geometry of the grating arrangement and by the light wave lengths λ_1 , λ_2 , .. etc. used or, respectively, by the channel spacings. A retaining surface having etched-in holes at appropriate
25 spacings can likewise be used in place of the grooved

mechanism 20. In this case the fibres are similarly held in exact spacing by being bonded into these holes.

Such a fixing mechanism 20 usually consists of
5 a precision component which is made from an aluminium/
brass alloy and which is very expensive and complex
to produce. Furthermore, for each special application
of the demultiplex system a new fixing and guidance
mechanism adapted to the light wave lengths used for
10 the individual channels and to the particular grating
geometry has to be produced. In other words, the
fixing and guidance mechanism effectively fixes the
light wave lengths which can be used in the multiplex
signal.

15 An object of the invention is to provide optical de-
multiplex transmission equipment, of the kind described
at the beginning hereof, in which no complex guidance
mechanism for the light conductors intended for de-
coupling of the individual light signals is necessary.

20 A further object is to provide such equipment
wherein a change in the channel spacings and/or the
wave lengths of the light signals of a multiplex

signal that is to be processed is possible without structural changes being necessary.

These objects are achieved by provision of optical demultiplex transmission equipment of the general type described at the beginning hereof wherein the surfaces of the output light conductors are arranged close together in the region of their input ends and wherein the light transmitters (L_1' , L_2' , L_3' ... etc.) emit light signals having predetermined wave lengths (λ_1' , λ_2' , ... etc.) selected such that the light signals diffracted by the grating impinge in each case only on every n th input end of the output light conductors, in which respect n is a natural number greater than one.

As a result of these measures a piece of optical demultiplex transmission equipment is provided in which the light conductors intended for decoupling the individual light signals of various wave lengths are arranged close together in the region of their input ends and in which only every 2nd, 3rd, ... or respective n th light conductor is acted upon with a light signal of respective wave length. The respective

diffraction angle is so adjusted, by varying the wave length of the light signal of each channel, that the diffracted light beam falls on the input end of the corresponding output light conductor. Thus, a
5 special guidance mechanism for the output light conductors is superfluous and the optical demultiplex equipment in accordance with the invention can be produced at lower cost than the known equipment described above. Moreover, the equipment in accordance with
10 the invention can be used, without constructional changes, in conjunction with various light wave lengths, or, respectively, various channel spacings. Also, a change of individual wave lengths of a multiplex signal can readily be carried out with the
15 equipment in accordance with the invention provided only that there is at least one further light conductor not used up till then lying between two channel-conducting output light conductors.

In this way the spacing between the individual
20 output light conductor fibres 16 can be better adjusted to the respective output wave lengths. Such a light conductor bunch or bundle can be shifted for optical tuning depending on the degree of efficiency of the reflection grating 12 in block displacement.

A preferred exemplified embodiment of the optical demultiplex transmission equipment in accordance with the invention will be described hereinunder with reference to Figure 2 of the drawings.

5 In the exemplified embodiment shown in Figure 2 the same reflection grating 12 is used which has already been described in connection with the conventional demultiplex arrangement shown in Figure 1. The components in Figure 2 which are the same as those in
10 Figure 1 are therefore provided with the same reference symbols and will not be explained in any further detail to avoid unnecessary repetition.

 In the optical demultiplex transmission equipment
10 in accordance with the invention, in the regions of
15 the output light conductor fibres 16 contiguous to the input ends 18 thereof, the peripheral surfaces 17 of the fibres 16 are arranged close together side-by-side in the diffraction plane of the dispersion grating
12. The input ends 18 of the output light conductors
20 fibres 16 butt against that side surface 13 of the body 11 which lies opposite the reflection grating 12

and they are fastened there, for example with an adhesive which is transparent in the relevant wave length range. The peripheral surfaces 17 of the light conductor fibres 16 can be bonded to one another and/or be fastened on a flat common carrier (not shown).

If each of the light conductor fibres 16 of this arrangement were to be used for decoupling a light signal, the channel spacing, i.e. the difference in the wave lengths of the light signals decoupled by way of two adjacent light conductor fibres 16, would have to be selected to be correspondingly slight, but the separation of adjacent channels would also be reduced to a few dB (decibels). For decoupling the individual light signals of different wave length, only every n th light conductor fibre 16 is used, in which respect n is a natural number greater than 1. The value of the number n depends on the necessary channel separation and on the channel spacings of the individual light signals one from another.

Figure 2 illustrates the case where $n = 2$. In each case a single fibre 19 which serves merely as a spacer is arranged between the signal-conducting light conductor fibres. These spacer fibres 19 can, in the appropriate circumstances, be cut off at a specific

of the
length from the body 11. The diameter_A gradient
fibres, which are usually used for this purpose, is
about 125 μm . A distance of 125 μm between two
signal-conducting light conductor fibres 16
5 suffices, as a rule, to guarantee an adequate
channel separation. The spacing can, however, be
doubled, tripled and so forth, by only every 2nd,
3rd, 4th .. etc. light conductor fibre 16 receiving
a signal. In other words, with a preset reflection
10 or dispersion grating arrangement, in order that the
individual light signals, of the various channels
which are separated at the diffraction grating
impinge exactly on the entry ends 18 of the
corresponding output light conductor fibres 16, the
15 wave lengths λ_1' , λ_2' , λ_3' , ... of the individual
light signals have to be so varied that the diffraction
angles θ_1' , θ_2' , ... are adapted to the arrangement
of the second light conductor fibres 16.

As previously mentioned, lasers are usually
20 used as the monochromatic light transmitters L_1' ,
 L_2' , ... etc. When this is the case, the wave length
of the emitted light λ_1' can be varied by changing
the temperature of the laser (approx. $0.3 \text{ mm}/^\circ\text{C}$). Thus, for
each light signal, the temperature of the correspond-
25 ing laser L_1' is so adjusted that light with the
wave length λ_1' (corresponding to the laser tempera-

ture) is diffracted at the reflection grating 12 at such an angle θ' that the diffracted light beam falls on the input end 18 of the second light conductor fibre 16 intended for decoupling this
5 light signal.

A light conductor fibre bunch for decoupling the individual channels of a multiplex signal usually consists of about forty to fifty light conductor fibres 16. If, for example, five to ten different
10 channels are superimposed in a multiplex signal, a user has considerable freedom to select the spacings between the signal-conducting second light conductor fibres 16 in accordance with the desired channel spacings and to select the laser transmitters (from
15 those available on the market, at any one time) having the necessary channel separation.

In the multiplex transmission equipment 10 shown in Figure 2, a reflection-dispersion grating 12 is used. The invention is not, however, restricted to
20 the use of such gratings. Indeed, the invention also applies to demultiplex equipment incorporating other available dispersive optical components, such as through-transmission diffraction gratings etc. In each case the adaptation of the light propagation
25 paths of the individual signals to the respective geometry of the dispersive optical component used is

effected by way of the variation of the wave lengths of the light signals. Furthermore, various kinds of light transmitters, such as semiconductor lasers, gas lasers or LED-elements, can be used. All that is
5 essential is that the emitted wave length can be varied and that it is substantially monochromatic. In the case of lasers, this wave length variation can be achieved by changing the laser temperature, but it can also be achieved in other ways, for example, in the case
10 of gas lasers, by adjusting the etalon or standard or by resonator systems which have a wide range of variations.

The output light conductor fibres 16 may have a diameter of about $100\ \mu$ in the case of monomode version
15 and a diameter of about $240\ \mu$ in the case of multimode version. However, they are surrounded with a jacket (coating) giving a greater thickness.

The input ends 18 of the output light conductor fibres 16 may be etched so as to accurately define
20 their outside diameter so that they lie at a predetermined spacing relative to one another. Hydrofluoric acid (HF) may, for example, be used as the etching medium.

CLAIMS

1. Optical demultiplex transmission equipment comprising several light transmitters for generating several light signals of discrete wave lengths, a dispersion grating, a first light conductor which is
5 directed at the dispersion grating and conducts a multiplex signal formed by superimposition of the light signals of various wave lengths, and several second light conductors which are arranged side by side in each case with an input end in the diffraction
10 plane of the dispersion grating for separate decoupling of the individual light signals of the multiplex signal, characterised in that the surfaces of the second light conductors are arranged close together in the region of their input ends, and in
15 that the light transmitters emit light signals having predetermined wave lengths selected such that the light signals diffracted by the grating impinge in each case only on every n th input end of the second (output) light conductors, in which respect n is a
20 natural number greater than one.
2. Equipment as claimed in claim 1 wherein the light transmitters comprise lasers.



3. Equipment as claimed in claim 2 wherein the wave length of the laser light of each light transmitter is tuned by adjusting the laser temperature.
4. Equipment as claimed in claim 1, 2 or 3 wherein the
5 peripheral surfaces of the second light conductors are bonded to one another in the region of their input ends.
5. Equipment as claimed in any preceding claim further including a flat common carrier to which the second
10 light conductors are fastened in the region of their input ends.
6. Equipment as claimed in any preceding claim wherein the second light conductors not receiving a light signal are cut off after a specific length.
- 15 7. Equipment as claimed in any preceding claim wherein the first and second light conductors consist of light conductor fibres.
8. Equipment as claimed in any preceding claim wherein the second light conductor fibres are etched to specific
20 diameters in the region of their input ends.
9. Optical demultiplex transmission equipment substantially as hereinbefore described with reference to and as illustrated by Fig. 2 of the accompanying drawings.

