Development of Manufacturing Equipment for D-WDM Related Devices

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ABSTRACT The increasing demand for D-WDM (Dense Wavelength Division Multiplexing) related devices such as optical devices or optical components requires manufacturing equipment to be more efficient in productivity, of higher quality and more compact. Furukawa Electric has been developing many types of manufacturing equipment and testing apparatuses for these D-WDM related devices. In this report, three types of manufacturing equipment are introduced: a fully automated scribing and chip-cleaving machine for cutting an LD (Laser Diode) bar into many chips, an LD chip aging apparatus, and the automated alignment machine which is the core technology in optical component fabrication.

A reduction in cost of D-WDM related optical components is strongly being demanded by customers; in addition, new machines in this field are constantly being introduced into the market. Therefore, we have to develop new machines which manufacture competitive products considering the various needs stemming from research and development groups and from manufacturing groups. We are also planning to sell these machines to companies in Japan and overseas.

1. INTRODUCTION

The demand for D-WDM related optical devices and components is rapidly increasing, resulting in the need for mass-production manufacturing facilities designed for more effective productivity, higher quality and compactness. Since Furukawa Electric manufactures optical semiconductors, the manufacturing equipment for these D-WDM related devices that we have developed have lots of technical know-how that dedicated machine manufacturers lacking in.

Here, three types of machines are introduced: fully automated scribing and chip-cleaving machine for cutting an LD bar into chips, aging apparatus, and automated alignment machine which is the core-technology in optical components fabrication.

2. FULLY AUTOMATED SCRIBING AND CHIP-CLEAVING MACHINE

2.1 Outline

This machine has been developed in order to fully automate the process of cutting an LD bar into chips. The bar is cleaved from a wafer. This method includes a scribing process in which the bar (LD chips are aligned along the bar axis) is scribed at each boundary of the chips; and a cleaving process in which the bar is cut into chips due to the scribing effect. The existing scribing and chip-cleaving process is divided into two processes: the scribing process and the cleaving process. An operator is needed for each process, therefore it is very inefficient. The fully automated scribing and chip-cleaving machine combines the scribing and chip-cleaving processes into one so that the new process is highly efficient and, as described later,

Photo 1 Scribing and cleaving machine

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greatly improves the yield rate of the products. Photo 1 shows an entire view of the machine. This machine includes three mechanisms: the precise positioning mechanism for cutting chips by image processing, the scribing mechanism, and the cleaving mechanism. A bar is fixed on the setting board using expandable adhesive sheet; then the bar is set on the chip-cleaving stage, and the chips are automatically cleaved simply by pushing the start button.

2.2 Mechanism for Scribing Position Recognition

In the present scribing process, the first scribing position of the chip has to be specified manually by the operator, and the bar is then automatically scribed at a fixed interval. The operator, therefore, always has to manually specify the first position of each bar.

We have developed a new machine with an automatic positioning mechanism for scribing using image processing. The bar image is captured by an CCD (Charge Coupled Device) camera positioned above, and a position is determined by pattern recognition; then position-correcting instructions are sent to the stage controller which moves in the *x*, *y*, and θ directions. If a suitable position is not taken, position detecting and correction continue until an appropriate cleaving position is selected.

2.3 Load Control Mechanism for Scribing

Scribing was usually done with a sharp-edged needle. The new machine uses a circular blade, shown in Photo 2. The circular blade can scribe a bar simply by pressing it on the cleaving position of the chips. The working point of the circular blade is not restricted to one point, but any position around the circle will do. Therefore, the blade lasts much longer. Another advantage is that if one point of the circular blade is damaged, other points are available by rotating the circular scriber several degrees; thus, the process has a very high productivity.

Figure 1 shows the control mechanism of the scribing force. The spring, which is fixed onto the stage, supports the circular blade, the fixing arm and the weight. The stage moves down to scribe the bar. When the stage moves further down to the point where the circular blade first comes into contact with the bar, the spring extends to apply the force onto the bar, which is a part of the total force including the weight of circular blade, fixing arm and the weight. The extension of the spring depends on the position of the stage; this enables the operator to control the scribing forces on the bar.

Photo 2 Scribing and cleaving stage

2.4 Cleaving Mechanism

The cleaving process was usually done manually. After scribing the bar, the cleaving process was carried out by applying a force with some tool, such as a knife, from the rear side of the bar. Ideally, chips should be cleaved into mirror surface by applying a force on the position scribed in the former process. When using the knife for cleaving chips, however, it is difficult to correctly set the knife-edge into the rear of the scribed position of the bar to get enough chips with mirror surface.

A characteristic of the cleaving mechanism of the new machine is that this machine can accurately apply a force on the scribed position using measured data recorded when scribing, thus resulting in accurate cleaving. The cleaving mechanism of this machine, as shown in Figure 2, consists of an upper head with projections and a lower block. The upper head accurately falls onto the scribing position to press the bar, and the contact points of the lower block and the upper head act as fulcrum and point of force, respectively, and then the bar is cleaved into chips precisely at the scribed position. Equal forces are applied on both the left and right side of the scribed line to obtain chips with smooth-surfaced cleavage.

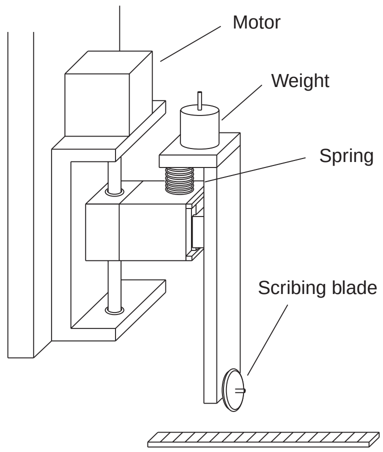

Figure 1 Scribing mechanism

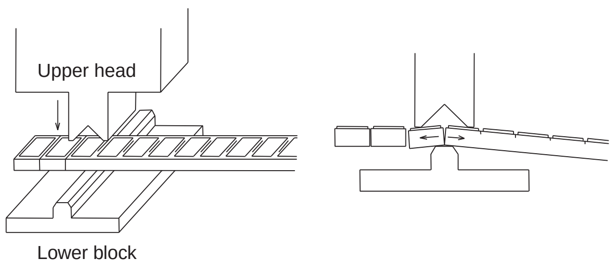

Figure 2 Cleaving mechanism

3. AGING APPARATUS FOR OPTICAL DEVICES

3.1 Outline of Aging Apparatus

Information communications systems of today require optical devices to be highly reliable. We are carrying out strict screening tests on all manufacturing processes to assure the quality of our optical devices. In the chip manufacturing process, to be more specific, long-term reliability tests are carried out for the chips in the can package, and in the butterfly-module manufacturing process, a much more restrict evaluation tests are done on the modules.

For the aging apparatus used in the screening test, highly accurate measurements and high reliability for the long-term automatic measurements are required. It is also necessary to upgrade the MMI (Man Machine Interface) in order for the operator to set the machine, and collect and analyze the data. In order to meet these requirements, we have developed aging apparatuses in our factory and have applied them in many of the manufacturing processes.

The features of the aging apparatuses are described below in the sequence of power source circuit for LD, thermostatic chamber, optical receiver for PD (Photo Diode), test board and computer system.

3.2 Power Source Circuit for LD

Power source circuits for LDs are provided in the range of 1 to 5 amperes to adapt to the circuit technology of our optical amplifiers.

Depending on the application, two types of control systems for aging are used. One is the ACC (Automatic Current Control) which keeps the load current to the LD constant, and the APC (Automatic Power Control) which keeps the optical output from the LD constant. In the core of the control system, a fast, high-performance 32-bit CPU is mounted to carry out various measurements and controls such as high-accuracy APC or other measurements necessary for aging.

3.3 Thermostat and PD Receiver

The thermostat consists of an LD chamber which accommodates test boards mounted with LDs and a PD chamber which accommodates PDs. The following two control systems are adopted in the PD chamber, depending on the application.

3.3.1 Normal APC System

This is a test system normally adopted, in which PD units as many as the LDs are arranged in the PD chamber. Silica light-guide is mounted between the LD chamber and the PD chamber. Light from the LD mounted on the test board travels along the light-guide to the PD unit.

3.3.2 Sampling APC System

This system includes one chamber of LDs (40 to 160 pcs) and one PD; the PD moves to the emitting facet of each LD in turn. LDs mounted on the test board emit light through heat-resisting glass to the PD. While the PD is illuminated, APC is conducted on this LD and after the PD moves to another LD, ACC is carried out at a current corresponding to the optical output. This sampling APC system uses a PD which has good temperature characteristics so as to restrict the aging effect by the PD to a minimum level. Occasionally, fluctuations in optical outputs occur due to the mounting and dismounting of test boards from the PD chamber during the aging test; however, the fluctuations are corrected by the automatic alignment mechanism for stable aging.

3.4 Test Board

The aging apparatus is designed to save space in consideration of the large quantity of LDs' aging, which results in a yield of 560 to 640 channels/machine for the 1 A class LDs (Photo 3).

The advantage of our high-density mounting system stems from its structure. The heat is dissipated from the LDs to cooling fins with minimized thermal resistance to produce excellent results. (See Photo 4).

Photo 3 Aging machine

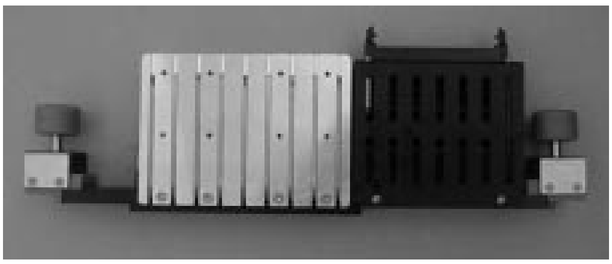

Photo 4 Test board for LD chip

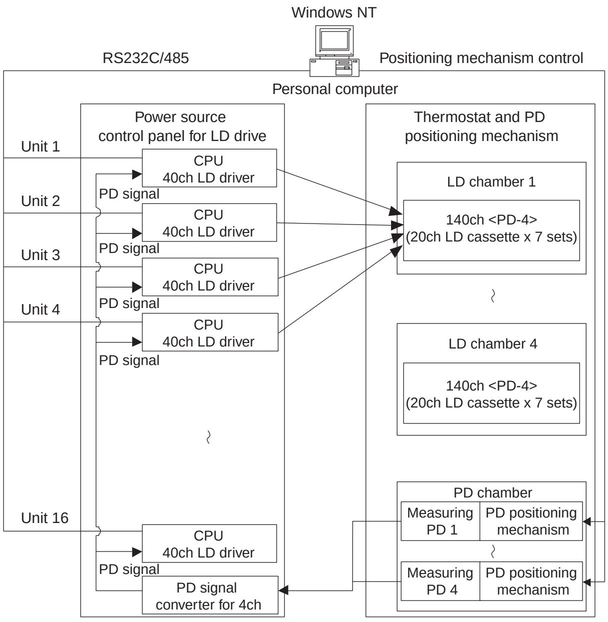

Figure 3　Block diagram of aging machine for LD chip

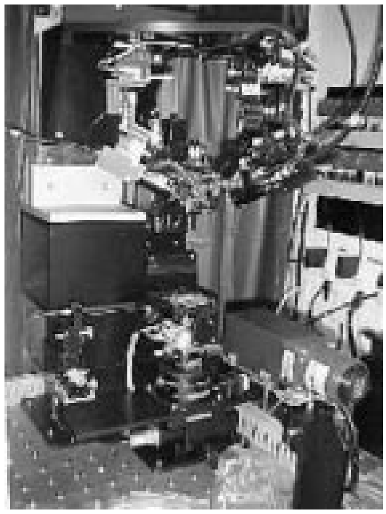

Photo 5　Fiber alignment machine

3.5　Computer System

Regarding the reliability and maneuverability of the system, it uses Windows NT and specifically designed application software. Therefore, the setting operation and responsivity control which are essential to the aging test are realized through interactive operation with a personal computer . As shown in Figure 3, this system contains the setting of a power source circuit for LDs, gathering of test data, and the control function for a positioning robot of PD (sampling APC system). The measured aging data are graphically edited easily by the MMI function of the PC, enabling it to transmit data to a host computer via LANs.

4.　FULLY AUTOMATED ALIGNMENT MACHINE

4.1　Outline of the Development

The alignment process is one of the key processes in improving productivity (shortening of tact time, non-skilled operation) of manufacturing machines for optical device modules. In the alignment process, the working time needed for manual alignment operation varies greatly depending on the operator's skill. The automated aligning controller available today has a long tact time causing a bottleneck in productivity. We have, therefore, developed an automated alignment machine with a much shorter tact time. This machine has high performance and is inexpensive, and not only is used in our factories but also is sold to users in foreign countries (Photo 5 is a fiber alignment machine for in-house use).

The following is an explanation of the optical device alignment and assembly machine and the features of our automated alignment machine.

4.2　Alignment and Assembly Machine for Optical Devices

In the field of optical devices, "alignment" means the spatial mating of optical axes between light-emitting and receiving elements, between optical fibers, and between light emitting/receiving elements and optical fibers. This alignment is done by setting a total of 6 degrees-of-freedom in position; optical axis direction (*z*-axis); two axes directions which are perpendicular to the *z*-axis (*x*-*y* plane); and three rotating angles around each axis (θ_x, θ_y, θ_z). Usually, the positioning of rotational directions of θ_x, θ_y, or θ_z is mechanically compensated (i.e., facet alignment mechanism, visual setting of θ_z, etc). In practice, *xyz* 3-axes alignment or *xyz* θ_z 4-axes alignment are used.

The method for aligning the elements or fibers is as follows: optical elements or fibers are held opposite to each other; one emits light and the other moves in the space to receive light, searching for a position with maximum optical coupling power.

4.3　Features of Automated Alignment Machine

The automated alignment machine uses "5 points alignment" which searches for the peak of the light intensity distribution in the *xy*-plane that closely resembles a two-dimensional curved surface. This method is for general-purpose use and the tact time is relatively short; therefore, it is available for various alignment applications. The optical intensity distribution along the *z*-axis direction is not very steep compared with the *xy*-plane, while the fluctuation of the intensity is great; therefore, additional ideas must be adopted in order for the peak not to be in local optimum.

The configuration of the hardware is as follows: stage control operates the pulse driver with the control board built into a personal computer to make the operation faster; the pulse driver can give a resolution of 0.004 to 1 µm/1 pulse by micro-step regulation. The optical power data is taken from GP-IB communications and also from the AD board to make the measurement faster.

By adopting these ideas, the tact time was shortened by 40% compared to conventional alignment machines. The price of the machine is much lower than automated alignment machines on the market due to the use of off-the-shelf parts available.

The most advantageous point of in-house manufacturing of the alignment machine is that it has made it possible to freely customize alignment operation in addition to increasing productivity by tact-time shortening or cost-cutting. In practical designing, it is necessary to understand the features of light-intensity distribution that various applications (fiber-alignment, lens- alignment, ferrule alignment, etc.) are dealing with so as to customize the automated alignment machines.The features of light-intensity distribution may be steep or not steep, and smooth or fluctuating. If fluctuating, whether measurement errors or other physical factors such as light interference cause it. This machine has the advantage of being able to respond to all in-house applications.

5. CONCLUSION

We have developed mass-product fabrication machines and testing equipment for D-WDM related optical devices, resulting in devices of high, stable quality and high productivity.

The field of D-WDM related optical devices is now growing larger and larger and new devices are always being introduced. We have to make an effort to develop new machines for our competitive D-WDM related optical devices considering the needs of our development and manufacturing sectors. Furthermore, we are planning to sell the machines to users in our country as well as overseas.

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