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Hybrid Integrated 8-Channel SOAG Receptacle Module with Driver Circuits

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I. INTRODUCTION

Large capacity switching systems based on photonic technologies are attractive toward achieving a high throughput telecommunication network for a large traffic increase [1]~[3]. These systems require a number of optical gates in their core switch fabrics. Semiconductor optical amplifier (SOA) is expected as the optical gate because of its inherent high speed and high on/off switching performances. It can also provide even signal gain, which enables loss compensation in the switch fabrics. Such SOA gate (SOAG) mounted on a waveguide platform in hybrid manner becomes to be considered as a key component for realizing such switch fabric [4][5]. The systems should also satisfy scalability, which strongly depends on performances of the gate modules such as insertion loss, crosstalk, module size, cost, etc. While the system gets so larger, board-level assembly such as complex circuits of many discrete devices and also layout of huge amount of complicated surplus pigtail fibers will become to be another important issue. From these points of view, hybrid SOAG array module integrated with optical/electrical interfaces such as connector receptacles and driver circuits seems to be the most useful form for realizing such system.

This paper describes the design concept, structure and performances of the developed hybrid integrated 8-channel SOAG array receptacle module, which has been enabled by our original hybridization and assembly technologies. Its applicability was proved successfully through the practical gating performances.

II. DESIGN CONCEPT & MODULE STRUCTURE

To realize the scalability of the switch fabric, both high gain and low crosstalk features are fundamental for the SOAG modules. These features strongly depend on the design of active-stripe geometry. A receptacle structure for the arrayed SMF connector is also indispensable to simplify the complicated fiber layout. Such arrayed receptacle structure, however, has not been realized yet. Besides, switching responses should be fast as short as 1nsec for the packet switching application, which is the same as that of high speed LD driver circuit. To overcome these problems for realizing practical SOAG module, we developed the following key technologies:

A. Receptacle Structure for Arrayed SMF Connector

To realize the practical receptacle structure for the arrayed fiber connector, we substituted conventional MT-compatible optical connector plug as shown in **Fig.1**. In case of the module, one end of SMF array (18mm long) was finished with the plug. The other end was aligned passively on the platform along the fiber guides, and then fixed with UV-curable adhesive. Typical coupling loss between the waveguide and the fiber was estimated to be less than 0.3dB. Typical insertion loss of the receptacle was about 0.5dB, and its deviation was less than ±0.2dB throughout the endurance test, which indicates the applicability of the structure.

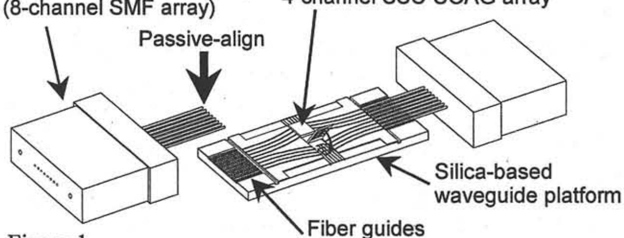

Figure 1
A schematic of the receptacle structure for arrayed SMF connector.

B. SOAG Driver Circuits

To achieve high speed switching performances for the packet switching application, we utilized a high speed LD driver IC with ECL-compatible signal interface for the driver circuits. Eight sets of the SOAG driver circuits were integrated on 12-layered ceramic package. Each circuit consists of the LD driver IC (Si-bipolar/STM-16), a voltage reference IC, a transistor, 6 capacitors and 12 resistors. Maximum output current, switching time and power consumption of the driver IC are 80mA, 100psec and 1.1W, respectively. To radiate such heat from the driver ICs to radiating plate on the back of the package efficiently, each driver IC and also the waveguide platform were mounted on a CuW block buried in through-hole of the package. Power supply for each of the circuits was completely isolated.

Employing these technologies, we developed the SOAG module as shown in **Fig.2**. It consists of a hybrid integrated 8-channel SOAG on silica based waveguide platform, a

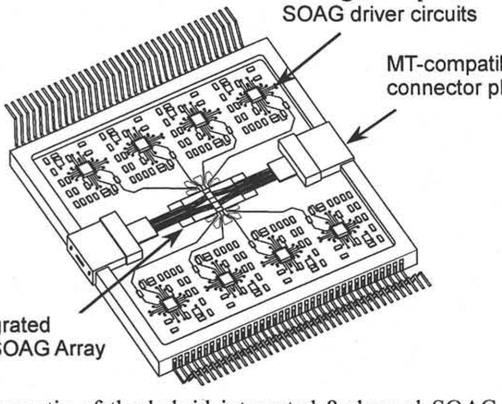

Figure 2
A schematic of the hybrid integrated 8-channel SOAG receptacle module with driver circuits.

couple of the receptacle connectors and the SOAG driver circuits. The module was assembled into the surface mountable ceramic package with 74 signal pins, and its size is 41mm×39mm×4.2 mm.

To suppress the inter-port crosstalk consistent with high signal gain, we adopted 4-channel SOAG array with arched active stripes [6]. The active stripes consist of polarization-insensitive bulk InGaAsP (λ=1550nm) with thickness-tapered spot size converters (SSCs). The angle of the stripe to facet was designed at 7 degree. Window region of 25μm long and AR coating were also adopted at each of the facets. The SOAG array is 900μm long and 1000μm wide.

Figure 3 is the photograph of the waveguide platform. The platform consists of eight pairs of silica-based optical waveguides, electrical signal lines and fiber guides on a silicon (Si) substrate of 12mm long and 4mm wide. The silica waveguide layer was formed by atmospheric pressure chemical vapor deposition (AP-CVD) using tetraethoxysilane /Ozone (TEOS/O_3) [7]. The waveguide couple to the SOAG was uniform bend of 11mm radius, which smoothly connected to straight region of 0.9mm long for the fiber coupling end. A couple of 8-channel fiber guides of 2mm long were located at both ends of the platform.

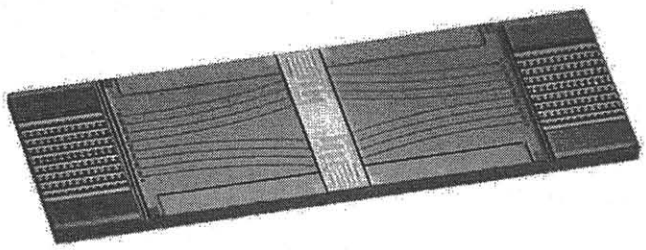

Figure 3
A photograph of the silica based waveguide platform.

On this platform, a couple of the 4-channel SOAG were mounted at once in flip-chip manner by our original self-align technique using stripe-shaped AuSn solder bumps [8]. In case of this module assembly, we employed novel fluid-assisted solder re-flow process. The technique is so practical because it enables precise alignment within ±1μm and also releases temporal chip-placing tolerance up to ±30μm, while it simplifies the conventional 2-step re-flow process in half. Gap between the SOAG and the waveguide was designed at 10μm. Coupling loss between the SOAG and the waveguide was estimated to be about 4dB.

III. MODULE PERFORMANCES

Figure 4 depicts the typical signal gain of the SOAG module versus injection current. The input signal wavelength was 1550nm and the power is -5dBm, respectively. The module gain as high as 2.6±1.1dB was achieved at 50mA of injection current. **Figure 5** shows the channel dependence of the on-off ratio at 50mA of injection current. Ideal high on-off ratio more than 40dB were successfully achieved. These static gating performances indicate the applicability of the proposed stripe geometry. High speed switching responses as high as 1nsec were also achieved under photonic packet switching.

These results support the promising features of the SOAG array module, which will provide a better solution to realize the switch fabrics in the future high throughput photonic packet switching applications.

IV. CONCLUSION

We developed the hybrid integrated 8-channel SOAG receptacle module with driver circuits by our original hybridization technologies, and its applicability was proved successfully through the practical gating performances. The module should be a key enabler to realize future high throughput photonic packet switching system for the next generation optical network systems.

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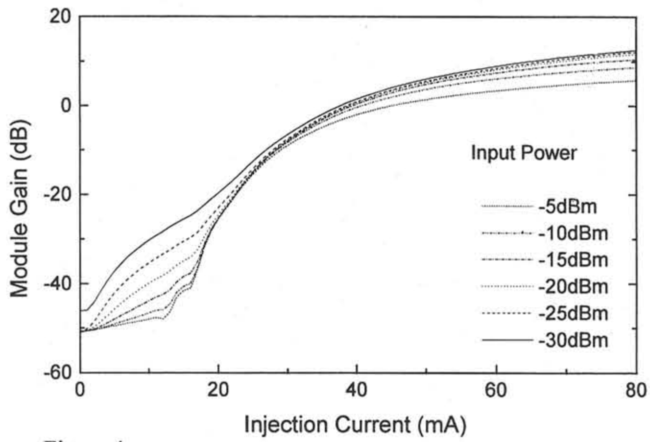

Figure 4
Typical module gain versus injection current.

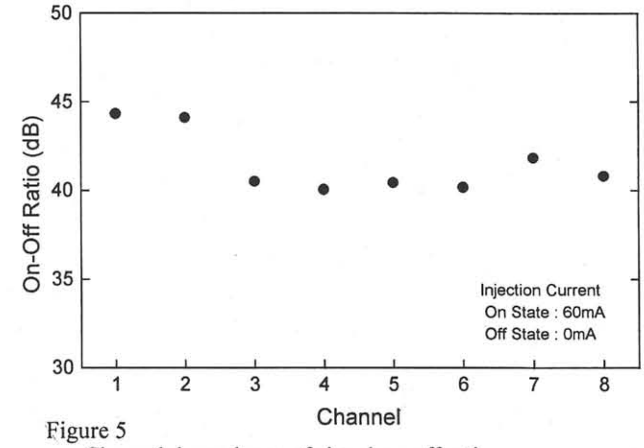

Figure 5
Channel dependence of signal on-off ratio.