Dual-Axis Optical Fiber Alignment using Gray-scale Technology

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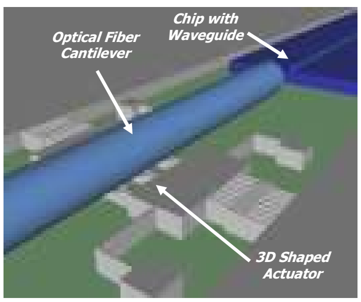
INTRODUCTION

***OBJECTIVE:** To actuate an optical fiber cantilever in 2-axes towards on-chip active fiber alignment for optoelectronics packaging*

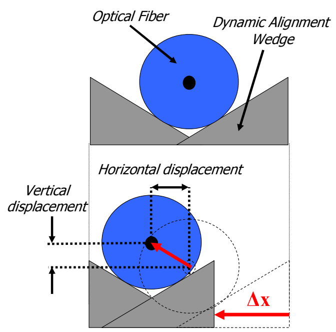
- Alignment of an optical fiber within an optoelectronics module often dominates cost
- Passive techniques are attractive, but rarely achieve the sub-micron tolerances that new devices may require
- On-chip active techniques could provide individually optimized fiber alignment within a package without the expensive and slow macro actuators currently required

CONCEPT AND DESIGN

Opposing comb-drive actuators with 3D wedges (fabricated using gray-scale technology) create a translatable, variable-height V-groove to alter the horizontal and vertical position of an optical fiber cantilever

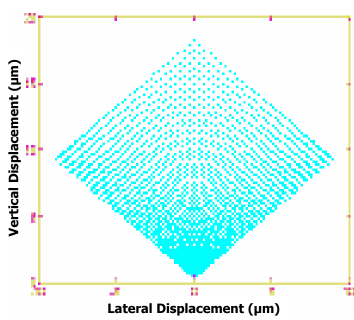


Concept of the 2-axis optical fiber actuator



Fiber before and after actuating a single wedge, demonstrating horizontal and vertical displacement

- A fiber cantilever is created by fixing one end (not shown in picture above) using UV-curing epoxy, while the free end rests between 3D silicon alignment wedges
- Coupled in-plane motion of the alignment wedges can control both horizontal and vertical fiber location
- In the simulation at right, each point represents the calculated fiber location for a set of voltages applied to independent comb-drive actuators
- Given the appropriate set of voltages, the fiber can be aligned to any point within this diamond-shaped plane

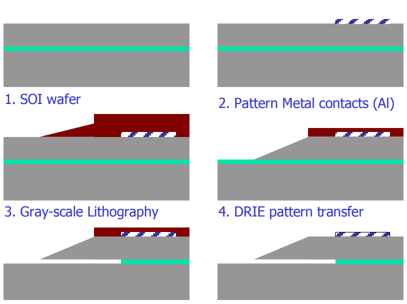


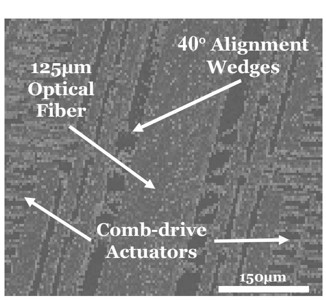
Simulated fiber locations given 45° wedges and independent electrostatic comb-drive actuators

FABRICATION USING GRAY-SCALE TECHNOLOGY

The required 3D silicon wedges, fabricated using gray-scale technology, were integrated with a standard SOI actuator process flow

- Gray-scale lithography uses a variable transmission mask to partially expose a photoresist film, leaving a variable height structure in photoresist after development
- DRIE transfers the 3D profile into the silicon substrate, where the relative etch rate of silicon to photoresist (etch selectivity) determines the final height/angle in silicon
- Thus, all planar and 3D silicon structures are patterned simultaneously, and buffered oxide etchant (BOE 1:6) is used to remove the buried oxide to release the actuator



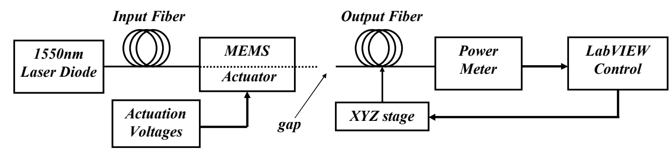


SEM of the fabricated fiber actuator

TEST RESULTS

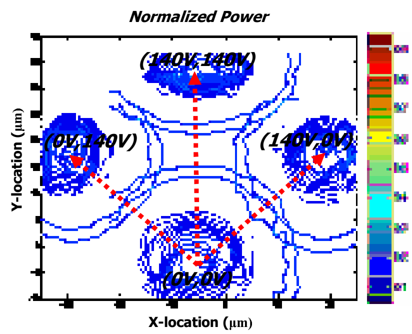
Fiber actuation behavior was evaluated using both optical coupling methods and non-contact profilometry

a) Fiber-Fiber Coupling



Layout of optical test setup for mapping fiber location

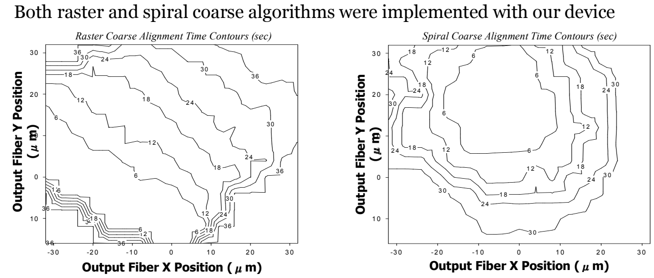
- A cleaved output fiber on an electrostrictive XYZ stage serves as a position sensitive power detector
- Fiber-fiber coupled power was mapped in the plane perpendicular to light propagation (LabVIEW)
- The peak coupled power of each 2D contour plot indicates the location of the input fiber core
- These 4 sets of applied voltages illustrate the diamond-shaped alignment area of the device



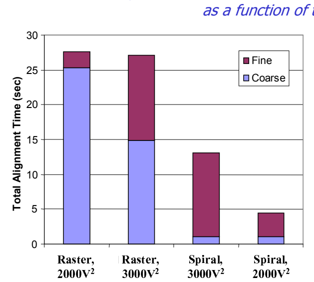
2D coupled power map for different applied voltages

b) Auto-alignment to Indium-Phosphide (InP) Waveguides

- Typical alignment algorithms consist of coarse and fine alignment steps
- Both raster and spiral coarse algorithms were implemented with our device



Measured time required to achieve coarse threshold using raster (left) and spiral (right) algorithms as a function of the output fiber location



Time to align within 1.6μm of an InP waveguide, as a function of search algorithm and Voltage² increment

- An indium-phosphide (InP) waveguide was added to the optical setup to serve as the alignment target
- Fine alignment was performed using a hill-climbing algorithm, where ΔV^2 describes incremental fiber actuation
- The partial and total alignment times show heavy dependence on coarse alignment algorithm and ΔV^2 setting
- Alignment within 1.6μm in less than 10 seconds was routinely achieved for this waveguide location

CONCLUSION

- We have presented the design, fabrication, and testing of a dual-axis optical fiber actuator that uses gray-scale technology to fabricate 3D wedges within electrostatic actuators
- We demonstrated an actuation range >30um in both the horizontal and vertical direction, as well as auto fiber alignment to an InP waveguide with 1.6um resolution

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