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COMB DRIVE ACTUATED CHIP WITH THREE DIMENSIONAL MOVEMENT

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Summary: The following work reflects the scientific results obtained during a staging process in Neuchâtel, Switzerland in the frame of an international project SCOPES IB no. 7420-1100981/1. In the work is presented the design of two concept models that are a modification of a chip based on comb actuation effect developed for the INTEL company. The models posses an additional Z axis movement for integrating a 3 plane movement of the lens platform for obtaining a better coupling efficiency of the laser beam in optic modules used in fibre optic communication systems.

1. INTRODUCTION

Precise and controllable delivery of laser beams or other guided modes to a desired location is an important topic, with telecommunications, and other general industrial applications. The most common means of obtaining such delivery is the use of large (i.e. macroscopic) mechanically controlled mirrors or lenses. While this technology is mature, it is limited by the mechanical nature of optical devices movement. Inertial properties of mechanically driven mirrors or lenses limit the speed with which steering direction can be changed. The other well-established beam steering device, the acousto-optic modulator, has a severely limited angular range [1].

There are many applications for beam steering. These devices may find uses in the following areas (among others):

- **Fibre-optic connectors**, in cases where it may be desirable to redirect the output of one optical fibre into another;
- **Laser displays**. For example, the use of a two-dimensional device for each of red, green, and blue lasers steering. The steered red, green, and blue lasers can be then recombined on some viewing surface to form static or moving images;
- **Imaging applications**;
- **Industrial applications**, such as laser cutting of metals or glass, in which a laser beam must be steered over a specific surface of material while the material is ablated along the desired cut line;
- **Free space communications**, in which data (being carried in a spatially directed modulated or pulsed beam) must be directed from one node in a communications link to another remote node and in which the direction from transmitter to receiver is not as rigidly fixed as would be required for non-steering communication;
- **CD-ROM** and related computer data storage devices, steering of reading or writing beam without requiring a moving carriage.

Steering of beams or deflection of light can be effected by the following technologies, among others:

- Mechanical Mirrors, driven by stepper or galvanometer motors;
- Acousto-Optic Modulator;
- DMD/DLP (the Texas Instruments technology);
- Grating Light Valve, (GLV);
- Inorganic Digital Light Deflection.

In many domains as telecommunications, optical measurements, etc, optical fibres are used. One of the most important challenges is to inject the light into the fibre. Nowadays, this is usually done either with large and expensive mechanical setups or passively aligned low cost modules, with much insertion loss. The goal of a collaboration research project SCOPES IB no. 7420-1100981/1 hold in Switzerland was to develop a new low-cost active alignment system to inject the light coming from a laser diode into a monomode optical fibre with minimum losses. The presented concept models are a modification of the actual chip work also on the comb actuation effect.

2. FUNDAMENTALS [3]

2.1. FIBRE ALIGNEMENT SYSTEM

A fibre alignment system is usually composed of a source of light (in our case, a laser diode), one or more lenses and the optical fibre (fig. 1). The lenses are spherical and macroscopic. After a first manual alignment, the fine alignment of the light into the fibre is carried out by moving the lens towards maximum intensity of light measured on the other side of the fibre. This is done by a feedback control loop.

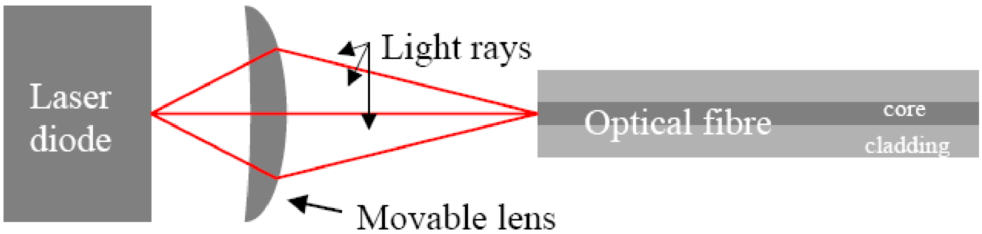


Fig. 1 Schema of a fibre injection system

2.2. COMBS DRIVE ACTUATION

Comb drives are often used in devices with structures held by mechanical springs. In the case of comb drives, we have an additional force due to the overlap perpendicular to the displacement.
If h is the height of the device, N_F is the number of fingers and g is the gap between the combs, the resulting force is:

$$F_E \approx -\varepsilon_0 \varepsilon_r \frac{hN_F}{g} V^2 , \tag{1}$$

As the elastic force of a beam is given by E_q. (2) where E is the Young's modulus, L is the length of the spring and t is its width:

$$F_E = \frac{Eht^3}{L^3} x , \tag{2}$$

The sum of the forces in the situation of Figure 3 is given by:

$$x = \frac{1}{2} \frac{\varepsilon_0 \varepsilon_r N_F L^3}{gEt^3} V^2 . \tag{3}$$

In this case, the displacement varies in function of the square of the voltage.

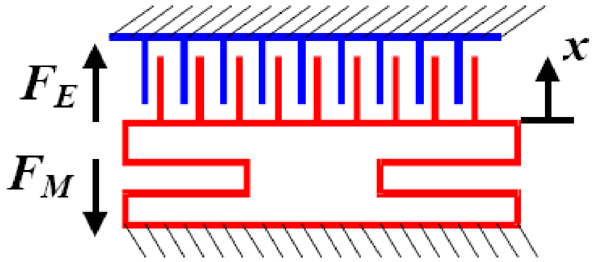


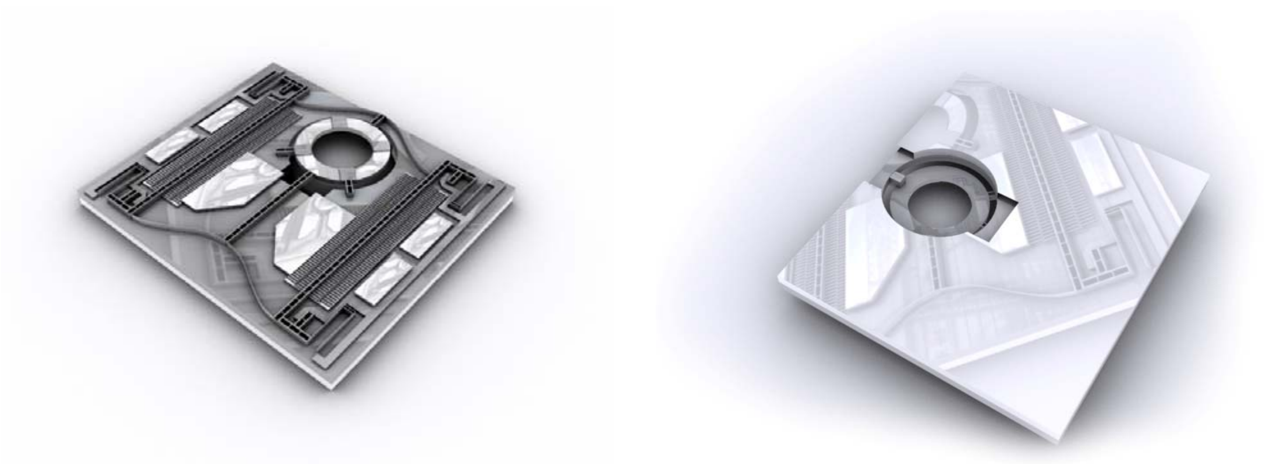
Fig. 2 Schema of comb drives held by springs

3. DESIGN

Depending on optical and packaging configurations, the design has to be adapted. In this chapter, the new design based on the novel silicon header packaging system developed at Intel will be presented.

Figure 3 shows a 3D drawing of the chip. Here are some of the construction characteristics:

- Two etching depths on front- and backside of the chip to obtain more complex 3D structures;
- Metallization on both chip sides;
- Circular platform with four small alignment structures for lens assembly;
- Focusing Lens.



a) *b)*

Fig. 3 3Ds Max image of the chip. a) Topside view. b) Backside view

4. 3D MOVEMENT CONCEPT (INTEGRATED Z AXIS)

Figure 5 shows the maximal theoretical coupling efficiency as a function of the distance variation between the laser diode and the lens and between the laser diode and the optical fibre. On this figure, one can see that the z-alignment is very important in the final packaging. Indeed, if the distance varies of five microns from the optimal position, the graph shows that the fibre has to be moved of several hundreds of microns. In this case, the maximal theoretical coupling efficiency drops to about sixty percent [5].

The represented optical setup is an old one, but the measurements and simulations made in fig. 5 correspond to this optical setup. The actual lens dimensions differ from those represented in fig. 4. The packaging alignment is not as critical in the plane perpendicular to the optical axis. If a misalignment occurs between the diode, the lens and the fibre, it can be compensated by moving the platform. This graph shows that the coupling efficiency is about the same after position compensation with the MOPOS chip [5].

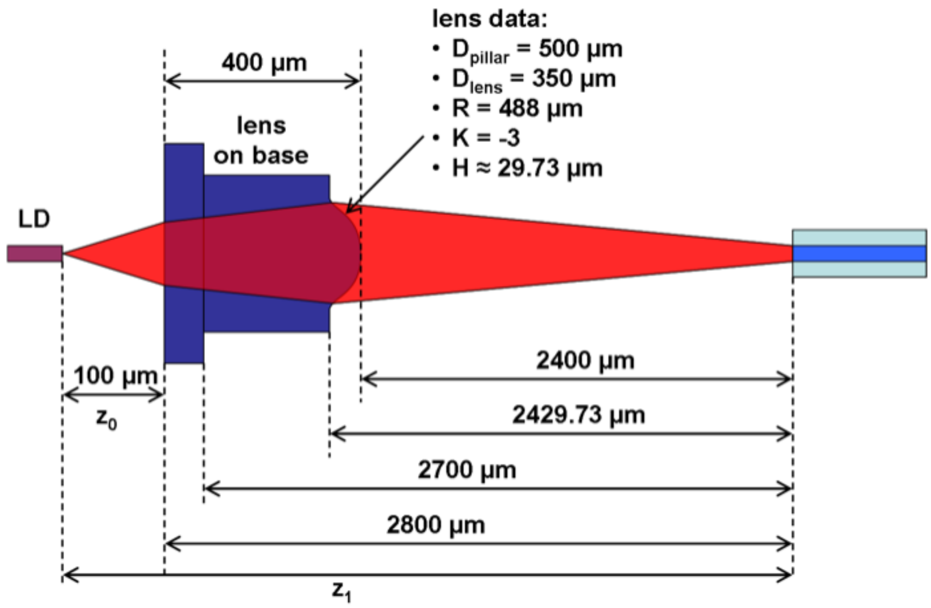


Fig. 4 Schematic view of the optical setup.

There have been made some tries of construction modelling with the purpose of introducing a Z axis movement, so that the problem with the packaging and optical setup could be solved. Of course, this involves some construction changes, and also this requires some changes of the fabrication technology.

The first construction model concept that was first designed with a special software 3Ds max is represented in figure 3.

Our suggestion was not to change very much the actual construction of the chip. In this case we added a third actuator which will provide a Z axis movement of the platform. The actuator was placed perpendicularly to the other ones so that it could move the two springs that are holding the moving platform.

After studying this construction, it was evident, that the current fabrication technology would not be enough to provide the construction and the position of the springs. In this case we will need a multilayer technology of fabrication. Of course, if we would use such a technology this model can be discussed further. And there can be done some tries of its fabrication.

In this construction, the two springs are moving a second platform that responds for the Z axis lift. The first platform is used for the X and Y movement. The second platform must be held by three vertical bars so that the second platform won't be displaced during the movement process.

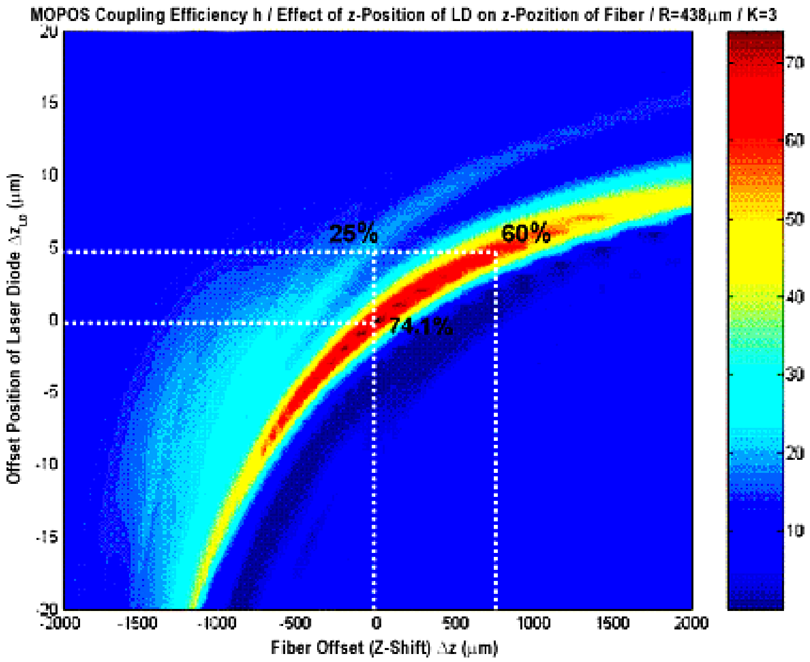


Fig. 5 FRED simulation showing the coupling efficiency as a function of the variation of the distances z_1 and z_0

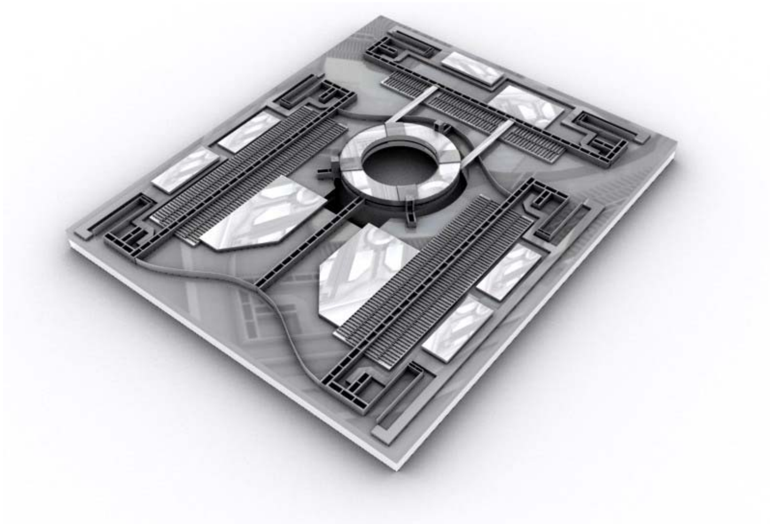
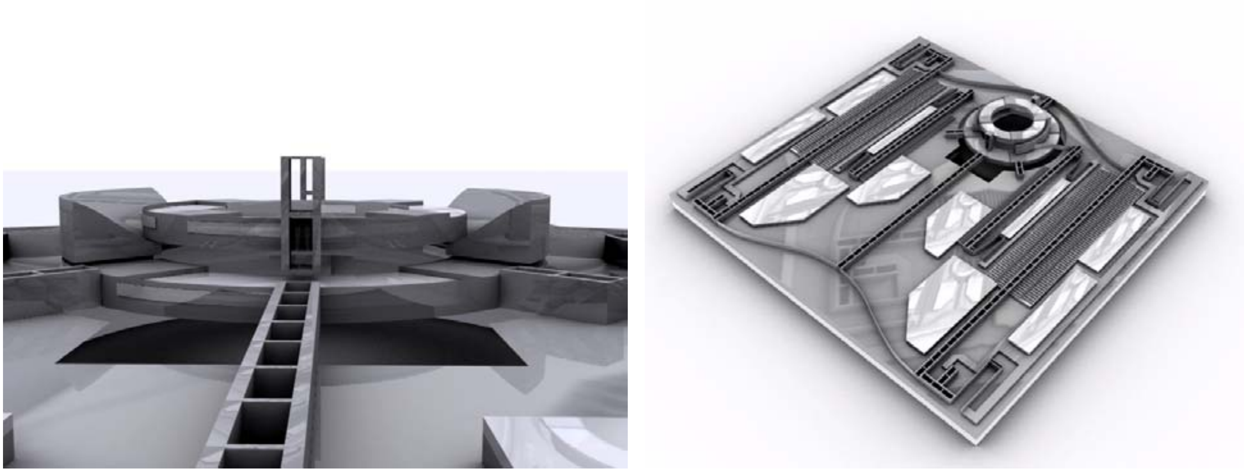


Fig 6 3D concept of an integrated Z axis on the chip
(in case of *.pdf version click on the image to view animation)

Thinking about a model that can be better adjusted to the fabrication technology used for fabricating the actual chip (without any Z axis movement) we tried to model a second construction of the chip with an integrated Z axis movement shown in figure 7.

In this case we added two more actuators that will provide a movement in the same plane as the other ones do (X plane). The movement of the both actuators must be opposite one to another one. This way we obtain the movement effect that we need. These two actuators are holding two pieces that have a special shape and form. Figure7 shows the shape of the two pieces that provide a Z axis movement.

The shape was modelled so that if the movement of the pieces is opposite to each other, the platform that is placed upon them should move upwards and downwards (along the Z axis).



a) b)

Fig 7 a: Shape of two pieces that provide a Z axis movement to the platform; b: Second 3D concept of an integrated Z axis on the chip (with opposite actuators).

The metal contacts have the same shape and form as it is at the other actuators. Of course, if we discuss the possibility of integrating this system on the same chip (with the same dimensions) this means that the added actuators must have smaller dimensions so that they could fit the actual construction of the chip. But we think that the best construction is the one with an increased x axis dimensions.Taking into the account the fabrication technology this construction is quite hard to be done. A possible way to be done is to fabricate it in several phases.

The first phase is probably the main chip construction. After that, there could be fabricated the actuators that provide the two pieces movement on a separate wafer so that it could be bonded after with the first structure. The third phase would be the lens gluing on the platform and after that its mounting after a bonding of the holding bars that provide a stability of the platform while moving.

Of course, this involves a row of complex technology processes, among them some that can be hardly done to adjust the construction shown above.

The presented two concept models are of a big interest for the development of the actual communication systems, especially for using them in a optic module for coupling the optic fibre with the laser diode and the integrated Z axis would give a great possibility of improving the characteristics and the properties of the coupling modules of an fibre optic communication system.

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