Micro-engineered two-dimensional arrays of single-mode optical fibres

Basic Technology Research Programme
RESEARCH COUNCILS UK
A 1000 micro-emitters per square millimetre

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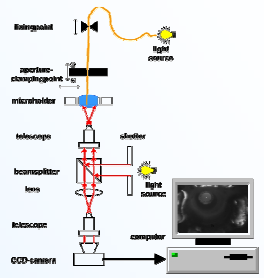
Introduction

To increase the manufacturability of 2D fibre arrays for mass production, a novel active alignment scheme is presented. The fibre ends of commercial, copper-coated single-mode fibres are inserted into individual holes in a microholder chip. These holes have been filled with UV curable glue beforehand. Each hole is surrounded by four electrodes, which are connected to four independent voltage generators. The electrostatic force, generated between one of the voltage-activated electrodes and the fibre, is used to move the fibre inside the hole. A fibre tracking system is used to determine the actual fibre position with respect to its desired final position.

System characterisation



Schematic diagram of the setup used for the device characterisation

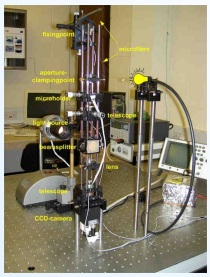
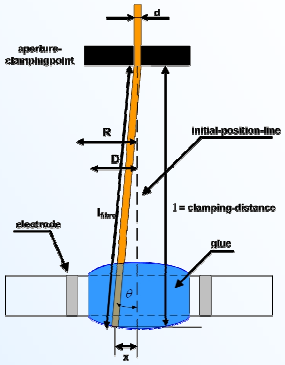


Photo of the setup used for the device characterisation

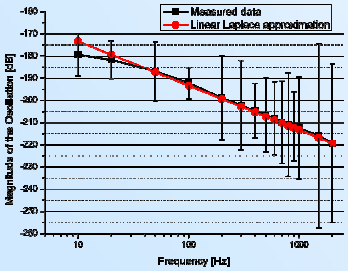
To characterise the dynamic behaviour of the electrostatic alignment procedure, an experimental setup was constructed and the test vehicles tested extensively.
The microholder is placed horizontally in an optical mount to negate the gravitational effects on the fibre. The fibre is electrically grounded using a clamping device placed at a certain height over the microholder, as shown in the figures on the left. A CCD camera is mounted below the microholder to detect the light coupled into the fibre core as well as capturing images of the fibre position and displacement. Using a video grabber card, the images from the camera are processed by a PC in real-time to calculate the actual position of the fibre core.
By applying either a voltage step or a sinusoidal voltage to a single electrode, the step- or frequency-response of the system can be recorded, respectively.

System model

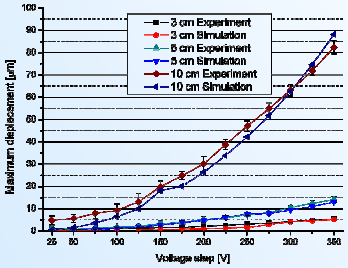
Using the geometrical model shown to the right, an analytical set of equations describing the system behaviour has been derived.
When the fibre end is inserted into the microholder chip and voltages are applied to the integrated electrodes there are four different forces affecting the fibre. These have been described in closed–form expressions and the results derived, compared to experimental data. Results for the step response and the frequency response of the system are shown beneath.



System model of fibre inserted into microholder



Frequency response: experimental data compared to simulated results

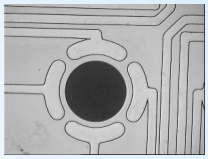


Step response: experimental data compared to simulated results

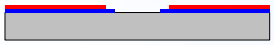
Microholder manufacture

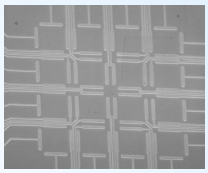
A modified UV-LIGA process has been used to manufacture the microholder devices on a glass substrate. Successive lithography and electroplating steps are used to form the three dimensional structures. In a finishing lift off process the titanium seed layer is dissolved to detach the micro holder from the glass substrate.

Step 1 Seed Layer deposition

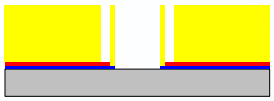


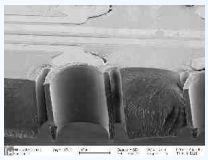
Step 2 Electroplating of Connection Tracks



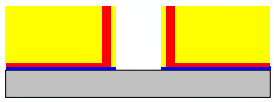


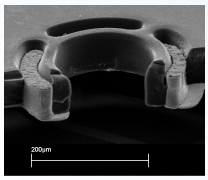
Step 3 Forming microholder body using thick film photoresist SU-8



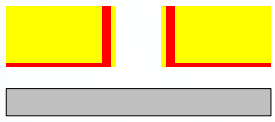


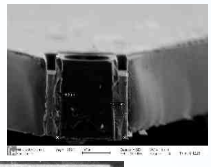
Step 4 Electroplating of Electrodes

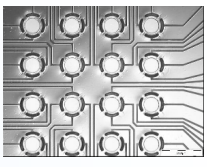




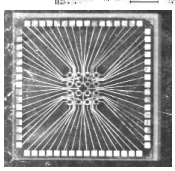
Step 5 Detachment of microholder from Glass Wafer







Central area of a manufactured 4x4 array.



Manufactured 4x4 array microholder device

Achievements

- The method of electrostatically induced fibre actuation is capable of precisely positioning single-mode optical fibres at sub-micron accuracy and fabricating two-dimensional fibre arrays.
- An array of 1 x 1 fibres has been produced in collaboration with IMM Mainz and its functionality tested.
- An array for 4 x 4 fibres has been produced in collaboration with Fachhochschule Kaiserslautern.
- The dynamic behaviour of the system has been simulated to originate a control algorithm for the active closed-loop feedback fibre alignment.