Remotely Powered Optical Switch for Remote Subscriber Aggregation and OTDR Measurement in PON

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Abstract *We present for the first time remote powering of a 3-D MEMS for optical switching using light over fibre. The low power switch with integrated optical splitters is suitable at non-powered remote PON distribution sites.*

Introduction

The rapid deployment of fibre-to-the-home (FTTH) poses a number of new operational challenges in managing fibre due to the growing outside fibre plant infrastructure and the inherent churn in access networks [1]. Automating fibre management using remotely controlled optical switches has been proposed to efficiently manage subscriber connectivity and fault localization without human intervention, and to reduce the number of network and test equipment [2]. Early field trials have confirmed the benefits to operate and maintain fibre-based networks [3]. The deployment of switches in Central Offices (CO) for FTTH point-to-point networks is relatively simple. The insertion of optical switches, however, in Passive Optical Networks (PON) at Fibre Distribution Hub (FDH) sites in the field is much more difficult because those sites are usually not powered. We demonstrate in this paper a remotely powered fibre management solution using a low-power 3D-MEMS optical switch and a light-over-fibre powering technique. We also report improved environmental performance for field switch operation.

Integrated PON 3-D MEMS Switch

Fig.1 shows a typical FDH layout in a PON: a first bay with optical splitters is connected to the Optical Line Terminal (OLT) at the CO; a second bay with fibre terminations is connected to residential homes.

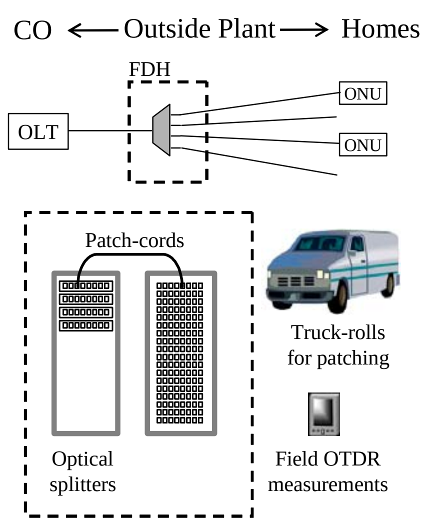

Fig. 1. PON FDH with discrete splitters and manual fibre management requiring technician dispatch to connect subscriber to OLT or test fibres with OTDR.

Each time a subscriber is added, a technician must be dispatched at the FDH site to connect it to an unused OLT port. If subscribers are connected up-front, additional OLTs are required due to limited market penetration, thus increasing greatly the initial investment cost per paying subscribe. Technicians also go in the field to perform OTDR measurements to certify fibre installation or to trouble-shoot faults.

All those costly and error-prone human interventions can be alleviated by the insertion of an optical switch at the FDH sites (Fig.2). The software-controlled switch connects a subscriber to the desired splitter port, packing subscribers onto the minimum number of OLTs in real time. All the home run fibres can be checked using a test fibre connected to an OTDR at the CO that can be shared among multiple FDH sites.

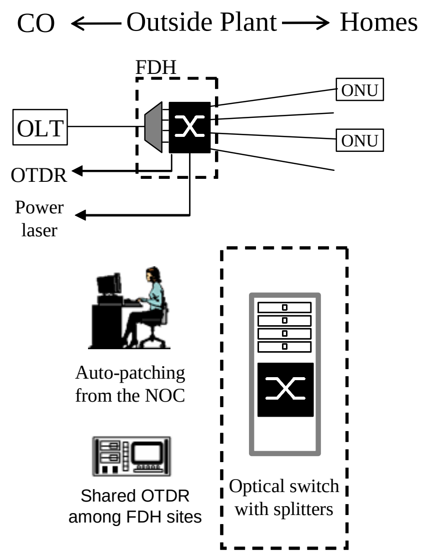

Fig. 2. PON Fibre Distribution Hub with 3D-MEMS switch with integrated splitters allowing remote subscriber aggregation and fibre testing

Fibre switching based on three-dimensional micro-electro-mechanical-system (3-D MEMS) technology is a great candidate because it has shown to scale to large port counts [4] while drawing low power in a small foot-print [5]. 3-D MEMS switches also demonstrate low loss (2 dB) over a wide range of wavelengths (1250-1650 nm), making them suitable for PON that typically uses 1310/1490 nm for upstream/downstream data communication, 1550 nm for video overlay, and 1625 nm for OTDR tests.

A prototype PON 3D-MEMS switch with integrated splitters was built using eight 1:16 input splitters (non-blocking 128×128 switch) and characterized. Each 1:16 splitter is directly spliced to the core switch, which allows a significant space reduction with fewer connectors and cables. Insertion loss including the splitter and the optical switch is typically 16 dB and less than 17 dB for all non-blocking paths.

Remote Powering of 3-D MEMS Switch

Power-over-fibre technology can deliver electrical power > 1 W [6] to remote nodes such as FDH sites in PON networks. Similarly to the test fibre used to run OTDR measurements from the CO, a fibre can be used to power the optical switch remotely as long as the switch requires low power.

3D-MEMS switches are attractive for remote powering because they are activated by electrostatic forces that draw very small current (~nA) although they require high voltages (~150V). For example, the electrical power drawn by the 3D-MEMS in a 320x320 switch matrix is under 10 μW.

However, the power required to drive a 3D-MEMS switch is dominated by the electrical circuit design. Therefore, the biggest challenge to limit the power consumption to about 1W is the electrical circuit design of the high-voltage mirror drivers and the high-voltage power supply to support them.

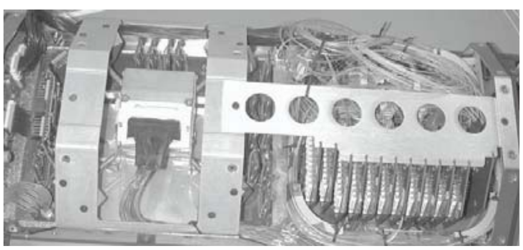

Fig. 3. 64x64 switch dissipating less than 1.5 W.

New switch module electronics, including low power MEMS driver circuits, have been developed to allow remote powering of a 64x64 switch dissipating less than 1.5W. The prototype switch is pictured in Fig.3. The packaging is very compact to allow the switch to be deployed in a constrained environment.

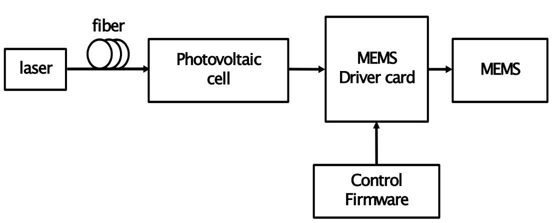

Fig. 4. Optically powered MEMS switch configuration.

Fig. 4 describes the electrical configuration that we used to demonstrate control of the MEMS mirrors optically over fibre. A laser is connected remotely over multi-mode fibre to a photo-voltaic cell that acts as the driver card power supply [7].

We also tested the low-power 64x64 switch over a larger temperature range than required for central office operation to check that the switch can be deployed in outside plant enclosures with no air conditioning. Figure 5 shows insertion loss variation over a wide range of temperature from -20 to 55 °C. The typical variation is less than 0.4 dB, as was the case for prior 3D-MEMS switches tested for CO operation [8].

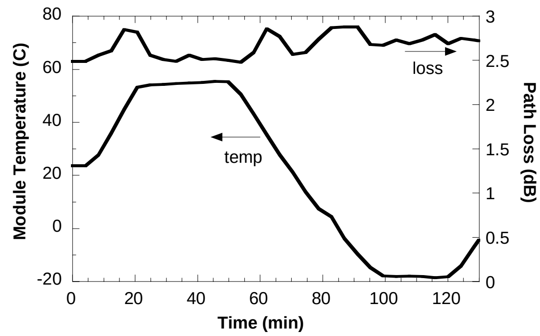

Fig. 5. Insertion loss of the low-power 64x64 optical switch as a function of temperature.

Conclusions

We demonstrated that 3D-MEMS optical switches are suitable to be deployed in the outside plant. We reported for the first time a 64x64 3D-MEMS switch requiring less than 1.5W which can be remotely powered, and demonstrated remotely powered 3D-MEMS mirror control. We also reported improved packaging density and environmental performance over a wide range of temperature, allowing such switches to be deployed in street cabinets or at the basement of buildings.

The deployment of automated fibre management solutions in PON offers significant benefits in terms of real-time subscriber aggregation and remote fibre trouble-shooting without requiring human intervention in the field. Further MEMS driver power reduction is in process to allow remotely powered switching sites to be scaled to 1,000 x 1,000 fibre capacity.

References

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