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Review Paper on Ultra High Capacity Indoor Optical Wireless Communication Using 2D Steered Pencil Beam

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Abstract — Free-space indoor optical communication deploying pencil beams can offer ultra-high wireless capacity individually per user device. By means of a pair of crossed grating 2D steering of multiple beams by just tuning the wavelength of each beam can be achieved by wavelength tuning from 1505 to 1630nm. With radio over fiber techniques and optical carrier from the downstream signal and upstream transmission of a 60GHz band radio signal has been shown using adaptive DMT modulation. Angular Magnification by lens system is used in future for increasing coverage area.

Keywords— *Indoor Optical communication, diffractive optical beam steering, diffraction grating.*

I. INTRODUCTION

An optical wireless communication system relies on optical radiation to convey information in free space, with wavelength ranging from infrared to ultraviolet including the visible light spectrum. A European Union funded project known as OMEGA has developed Gigabit home access network, as infrared optical wireless provides high speed indoor communication [1][2]. Due to the limited coverage area and spreading of light which implies that limited data rate in VLC (Visible light Communication), multiple directive beams are used, each individually pinpointing at a device and providing high capacity optical path to it [3]. These optical beams are directed by passive element based on diffraction grating concept, which perform wavelength tunable steering of multiple beams simultaneously in two angular dimensions to cover a room [4], [5]. Our system concept is shown in fig.1. Inside a building, each room is equipped with pencil radiating antenna (PRA). Each PRA can emit multiple optical pencil beams and the capacity per beam is at least 10Gbps. A point-to-point fiber link connects each PRA to the Central Communication Controller (CCC), where the tunable laser diodes are located. By means of an optical cross connect (OXC), according to actual traffic demands these laser diodes are mapped to the appropriate PRAs in the appropriate rooms. At the CCC, autonomic network management is located to intelligently locate and track the (roaming) users' mobile devices (MDs), and to control the OXC settings and the wavelength tuning accordingly. Machine learning techniques will be applied which gather user behavior characteristics, in order to speed up localization, tracking and beam steering processes. For the upstream path from the MD to the CCC, RF links in the 57-64GHz band are foreseen, to be picked up by an antenna at the PRA and carried over the fiber network. Inside a PRA, a passive diffractive module steers a beam in two angular dimensions, by just varying the wavelength of the beam. For this, we propose to deploy two crossed diffractive elements, see in fig.2, where one element has a relatively low diffractive power, and other one a high diffractive power. This passive PRA module steers a beam in two dimensional according to its wavelength. The wavelength of the beam acts as a control channel of the beam steering, embedded in the data channel; hence separate control channel is avoided, which relaxes network management and control. The wavelength tunable sources are hosted jointly in the central communication controller (CCC), connected to the PRA by means of an optical cross connect (OXC). A more efficient use of the network resources can be obtained when the capacity, generated by the multiple laser diodes in the CCC, is dynamically routed upon demand to those PRAs, which are in the vicinity of a user that requests service delivery. For the fibre backbone, bend insensitive single mode fiber and multimode silica or plastic fiber may be used. Multimode fiber can carry higher light powers, an thus better support the radiation of the pencil beams from the PRA. The cross connect routes each wavelength tuned data signal to the right PRA, upon control by the autonomic management system.

II. System Network

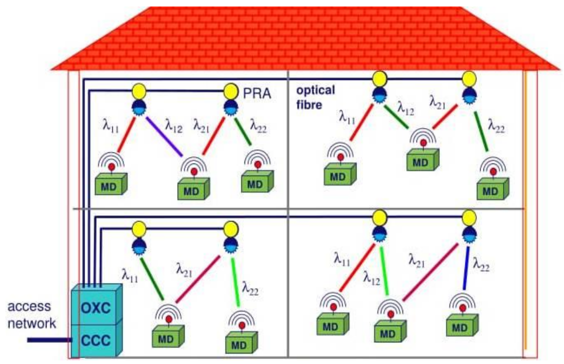

Fig.1 Free space indoor optical communication by pencil beam

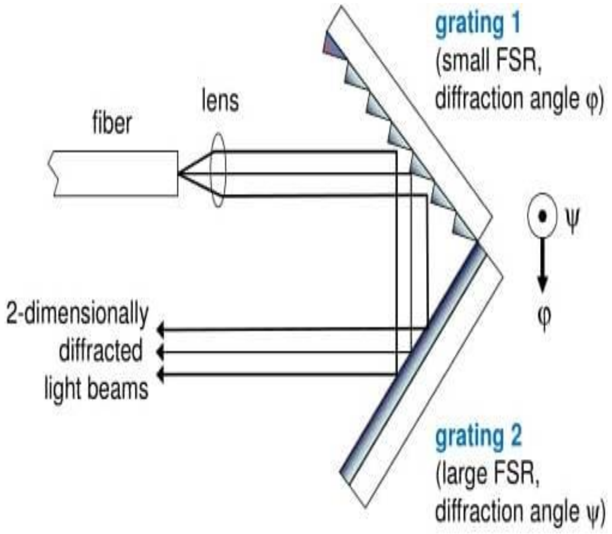

Fig.2 2D optical beam steering by a pair of crossed grating

A. Design of the 2D Beam Steering Module

We want to cover an area of L×L by means of 2D scanning of this area with a beam having a diameter D. The no. of scanning steps needed is

$$N = \left(\frac{L}{D_{beam}}\right)^2 \quad \text{… (1)}$$

And the no. of scanning lines is

$$M = \frac{L}{D_{beam}} \quad \text{…(2)}$$

Where L is the length and D is the diameter of beam so when a wavelength tuning range is available, the tuning step size is

$$\partial\lambda = \Delta\lambda/N = \Delta\lambda \left(\frac{D_{beam}}{L}\right)^2 \quad \text{…(3)}$$

Where Δλ is wavelength tuning range. When assuming that the receiver on the user terminal has an aperture with diameter Drx, the PRA is fixed in the middle of the ceiling at height H, and the power intensity in the beam is uniform across its diameter, the lowest power received in the elliptical spot in the corner of the room is

$$P_{rx\_min} = P_{beam}\left(\frac{D\_rx}{D\_beam}\right)^2\left(1+\frac{L^2}{2H^2}\right) \quad \text{…(4)}$$

When a diffractive element is used based on interference among a number of beams, interference maxima occur when neighbouring beams are in phase, so have an optical path length difference equal to an integer multiple *m* (i.e. the interference order) of the wavelength λ. The FSR for such element is found from the relation

$$m\cdot\lambda=(m-1)\cdot(\lambda+\Delta\lambda_{FSR}),\ \text{so}\ \Delta\lambda_{FSR}=\lambda/(m-1) \text{…(5)}$$

$$m(max) = \left(\frac{L}{D_{beam}}\right)\left(1+\frac{\lambda_{min}}{\Delta\lambda}\right) \text{…(6)}$$

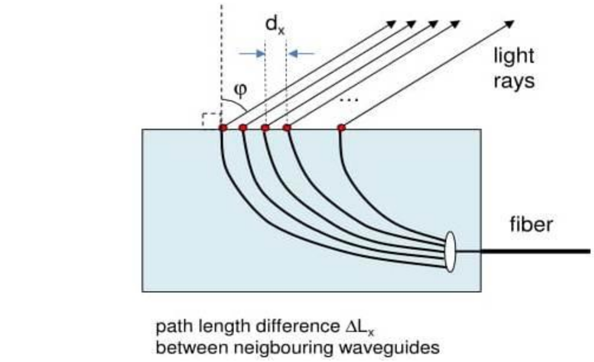

Fig. 3 Highly dispersive arrayed waveguide grating

this gives the highest order and such a high order is far beyond the capabilities of regular diffraction gratings. An element with high diffractive power operating in high order is the arrayed waveguide grating (AWG) and is given by the relation

$$\Delta\lambda_{FSR} = \frac{\lambda}{m-1} = \frac{\lambda^2}{\Delta\lambda + d_x \sin\varphi - \lambda} \quad \text{…(7)}$$

An alternative solution for obtaining a small FSR and high order m is the VIPA (Virtually imaged phased array.

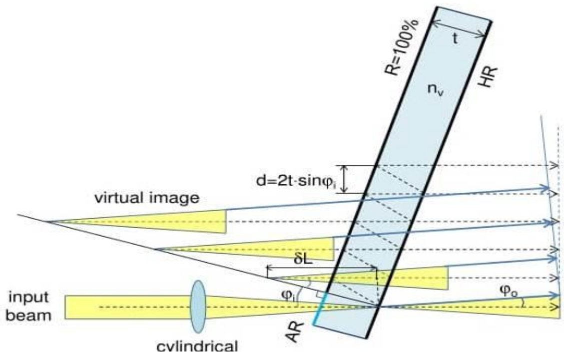

Fig.4 Virtually Imaged Phase Array

which is satisfies by the equation mλ = 2nt cos(φ-ϕ) where φ is the angle of incidence on the VIPA. According to the well known grating equation is $\sin\psi+\sin\theta = m\frac{\lambda}{d}$, where d is the groove spacing [4][5].

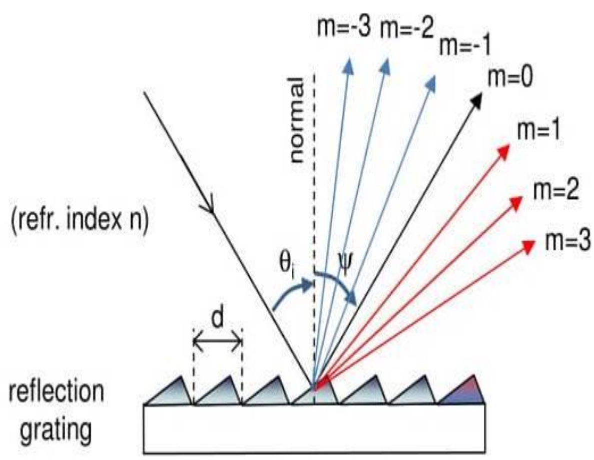

Fig.5 Reflection grating operating in various order m

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III. PROBLEM FORMULATION AND ANALYSYS

Various parameter are associated with the high speed indoor optical wireless communication which gives the possibility of better performance in system network, but sometimes these parameters create some problem and necessary to improve, which is

A. Requires minimum receiver sensitivity.
B. Provides an area of 32*64cm^2.
C. Photonic integrated circuit showed high losses[6].
D. In this point to point link is used to connect each PRA to CCC. The link should be bidirectional and the use of SLMs makes point to multipoint architecture feasible [7].

IV. PROPOSED SOLUTION

A point-to-point fiber link connects each PRA to the Central Communication Controller (CCC), where the tunable laser diodes are located. By means of an optical cross connect (OXC), according to actual traffic demands these laser diodes are mapped to the appropriate PRAs in the appropriate rooms. At the CCC, autonomic network management is located to intelligently locate and track the (roaming) users' mobile devices (MDs), and to control the OXC settings and the wavelength tuning accordingly. Machine learning techniques will be applied which gather user behavior characteristics, in order to speed up localization, tracking and beam steering processes[8].

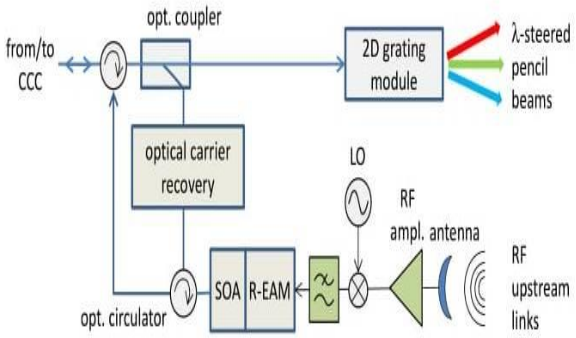

Fig. 6 Radio over fibre up steam path at PRA site, with optical carrier recovery

For upsteam path MD to CCC, 57-64 GHz band is used to pick up the signal by antenna by using RoF techniques. As shown in Fig.7, a laboratory system setup has been built for 2D beam steering, an echelle reflection grating with 13.3 grooves/mm operating in order *m*=95 at an incidence angle of 80.7° and wavelength λ=1550 nm, followed by a transmission grating with 1000 grooves/mm operating in *m*=1 and incidence angle of 49.9°. The optical carrier is generated by a Keysight laser to providing 13dBm output power tunable from λ=1505nm to 1630nm. After a polarization controller, via a triplet lens collimator with focal length *f*=18.4mm a pencil beam with 3.3mm beam waist diameter and up to 6dBm power is launched onto the crossed grating pair.

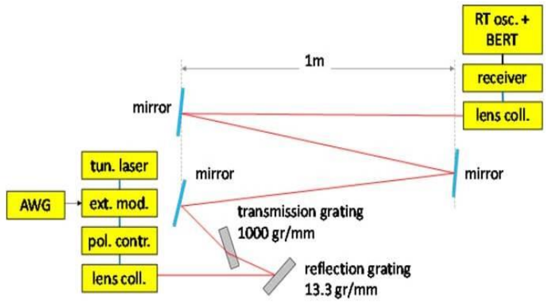

Fig. 7 2D beam-steered system experiment

Three silver-coated mirrors are used to fold the path of 3m total length. At the receiver side, a second lens collimator captures the beam, and signal analysis takes place with a real-time oscilloscope to observe the eye pattern and to analyze the BER. This second lens collimator needs to be aligned very carefully with respect to the first one in two angular dimensions, due to its very small field of view (only 0.034 degrees full angle). Total path losses in the link between the lens collimators are measured to be δ6.15dB for ⌊=1518 to 1600nm, which is 9.85dB less than in our previous setups with two reflection gratings. These path losses are mainly due to the losses of the two gratings; the three silver-coated mirrors contribute a reflection loss of only 0.11dB each [9].

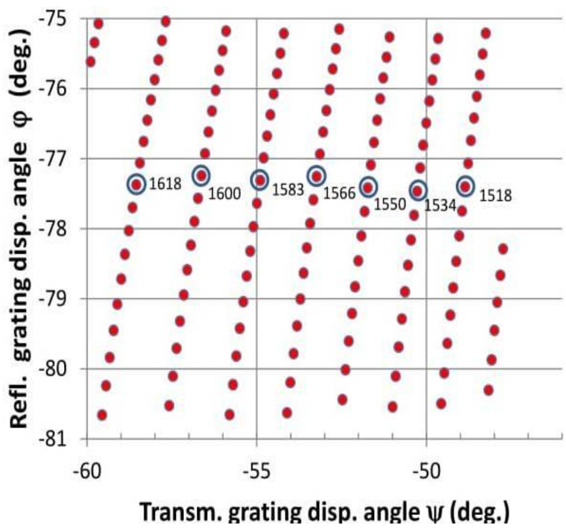

Fig. .8 2D beam scanning (simulated; encircled spots were measured at the wavelengths indicated)

Fig. 8 shows the calculated 2D-steered beam positions when λ is varied from 1505 to 1630nm, for which the order of the echelle grating varies from *m*=98 to 90, corresponding to the 9 scanning lines shown. Received optical powers measured in the encircled spots were between -0.15 and 1.2dBm. Angular tuning over 6° in the ϕ-range and 12° in the ψ-range is achieved. The dispersion of the two gratings together with the limited aperture of the receiver collimator sets the spectral pass band of the pencil beam channel. In our previous system setup with two reflection gratings we achieved transmission of 42.8Gbit/s using discrete multi tone modulation (DMT) with 512 tones and adaptive bit loading per tone. A maximum loading of 7 bits/symbol (QAM-128) was observed, decreasing to 1 bit/symbol at the edge of the pass band of the pencil beam channel.

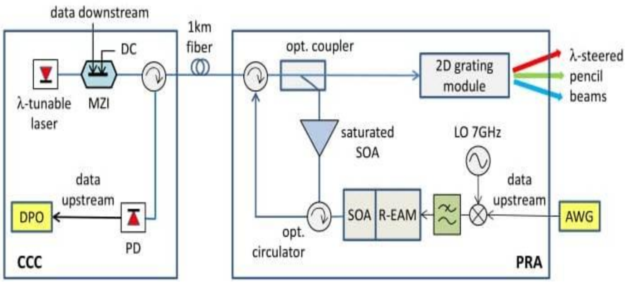

Fig. 9 Radio-over-fiber upstream system experiment

Excluding DMT overhead, the net transmitted data rate was 37.3Gbit/s. With respect to the DMT solution, the PAM-4 solution requires much less signal processing and thus offers the benefit of a much simpler receiver structure at the user's device[10]. It also offers less power consumption and lower latency. A preliminary system experiment for the upstream transmission path employing radio-over-fiber (RoF) techniques was carried out using the setup shown in Fig.9 Optical carrier recovery was implemented by using a semiconductor optical amplifier working in its saturation region. The radio upstream signal was emulated by an arbitrary waveform generator (AWG) operating in baseband followed by up-conversion using a local oscillator at 7 GHz. The resulting signal emulates the down-converted 60 GHz radio signal (with 7 GHz bandwidth) received from the mobile device. This radio signal then modulates the intensity of the recovered optical carrier (at λ=1550 nm) using a 10 GHz bandwidth REAM-SOA. The upstream RoF signal is launched into the 1 km fiber link with 0 dBm power. Rate-adaptive DMT modulation was used. At the CCC, the optical signal was received by a 10 GHz receiver and captured by a digital phosphor oscilloscope for signal processing.

V. FUTURE WORK

Angular Magnification by lens system is needed to achieve a practical FOV, which in turn induces some geometrical aberration and accentuates the beam broadening under propogation. Secondly for improving efficiency, reduced the diffraction order by which Angular dispersion is reduced. Fig. 10 shows the basic block diagram of Angular magnification used in system network in this way [11].

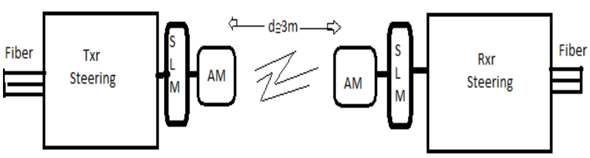

Fig.10 Block Diagram of simple methodology structure.

VI. CONCLUSIONS

Free-space optical communication deploying 2D steerable narrow optical beams can offer the ultimate in wireless capacity per terminal. The proposed concept employs a pair of passive crossed diffractive elements which enables scaling to large numbers of beams, each individually steerable by tuning its wavelength in the 1.5µm infrared regime. Delivery of 42.8Gbit/s per beam over 2.5m reach has been demonstrated. Careful design of the diffractive stages is needed to provide adequate area coverage.

REFERENCES

1. R. Remirez-Iniguez, & R. J. Green "Indoor optical wireless Communication" 15 Mar.2015.
2. Suchita choudhary, "Optical Wireless Communication –A future perspective for next gen. wireless system, International Journal of Scientific & Engineering Research, Volume 3, Issue 9, September-2012
3. Dr. Shikha Neema , Beena R.Ballal, Developments in indoor fiber wireless network, International Journal of Computer Science & Communication Networks,Vol 1(2),100-104
4. Koonen, C.W. Oh, K. Mekonnen, Z. Cao, E. Tangdiongga, "Ultra-high capacity indoor optical wireless communication using steered pencil beams,"IEEE, 2016, Paphos, Jun, 2016.
5. Ton Koonen, Joanne Oh, Ketemaw Mekonnen, Eduward Tangdiongga "Ultra-high capacity indoor optical wireless communication using steered pencil beam, MPW 2015, oct.2015, paper WeC-5.
6. InP Photonic Integrated Circuit with On-chip Tunable Laser Source for 2D Optical Beam Steering Weihua Guo, Pietro R. A. Binetti, Chad Althouse, Leif A. Johansson, and Larry A. Coldren, 2013
7. A.M.J. Koonen, C.W. Oh, E. Tangdiongga, "Reconfigurable free-space optical indoor network using multiple pencil beam steering," in *Proc. OECC/ACOFT 2014*, Melbourne, July 2014, Paper Tu3F-1.
8. K. Van Acoleyen, W. Bogaerts, R. Baets, "Two-Dimensional Dispersive Off-Chip Beam Scanner Fabricated on Silicon-On-Insulator," IEEE vol. 23, no. 17, Sep. 2011, pp. 1270-1272.
9. D. O'Brien, R. Turnbull, H. Le Minh, G. Faulkner, O. Bouchet, P. Porcon, M. El Tabach, E. Gueutier, M. Wolf, L. Grobe, J. Li, "HighSpeed Optical Wireless Demonstrators: Conclusions and Future Directions," IEEE/OSA J. Lightw. Technol., vol. 30, no. 13, Jul. 2012.
10. Lee S. C.J.(2009) Discrete Multi tone Modulation for short range optical communication.
11. Ariel Gomez, Crisanto Quintana, Grahame Faulkner, Dominic O'Brien "Challenges in Wide Coverage Indoor Optical Communications Using Fiber -Wireless-Fiber Links for Terabit data rates", IEEE 2015.