A monolithically integrated AWG based wavelength interrogator with 180 nm working range and pm resolution

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Abstract: A 1x16 AWG with an 87 nm Free Spectral Range is integrated with an array of photo detectors and used to detect picometer wavelength variations of a coherent light source.
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1. Introduction

Accurate wavelength measurement is crucial for a high number of applications related to optical sensing. Prominent examples are gas detection and strain sensing based on Fiber-Bragg-Gratings [1,2]. Recently, fiber based monitoring solutions showed great advances with relatively simple fabrication methods [3,4]. However, the high polarization sensitivity of fibers requires a stabilized experimental setup, which ultimately hempers the employment for many applications. Furthermore, the necessity of additional equipment is a limiting factor in cost, size and maintenance.

In this paper we propose a cost efficient Arrayed Waveguide Grating (AWG) approach for accurate and high-speed wavelength measurements. The monolithic AWG lacks moving parts, hence increases stability of the system and cancels long time scale related problems as mechanical fatigue. By designing the AWG such that two adjacent channels overlap, a change in wavelength can be monitored by evaluating the photo current of the corresponding photo detectors (PDs). First measurement results of a circuit based on a 1x16 AWG with an 87 nm FSR are presented. The periodicity of the AWG enables the operation over a significantly wider wavelength region than the FSR. We identify a working range of 180 nm with picometer wavelength resolution, limited predominantly by the tuning range of the available tunable laser.

2. Circuit Layout

The circuit is schematically depicted in Fig. 1(a). For simple packaging a straight input is connected to a 1x2 MMI power splitter, with one output connected to a reference diode and the other to the AWG. At each of the sixteen outputs of the AWG, a photo detector is placed forming 4 arrays of 4 detectors. The AWG design employs widened pass bands to increase the crosstalk level between adjacent channels. The wavelength meter is operated around the intersection of adjacent pass bands using balanced detection for increased output power. In Fig. 1(b) we display a photograph of the device fabricated in the COBRA generic process [5]. The metal contacts are conveniently routed to the edge of the chip. The footprint of a first non-optimized circuit is about 1.5 x 1.5 mm.

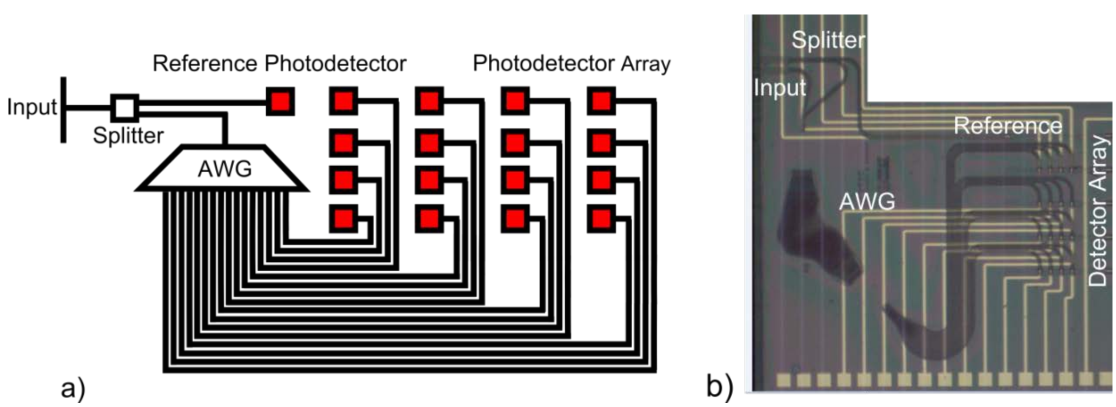

Fig.1: Schematic of photonic circuit containing integrated detectors, (a) Photo of PIC, containing the AWG based wavelength-meter with 16 integrated detectors (b)

3. Measurements

The device has been characterized using the setup depicted in the schematic of Fig. 2. A tunable laser, Agilent 81600B, is coupled via a collimating lense to free space. After passing through the polarizer, the collimated beam is coupled to the device via a microscope objective. A fiberized polarization controller is used to maximize the transmission throught the polarizer set to TE. The device is mounted on a copper element, which is cooled down to 293 K by a water cooler. Small temperature fluctuations are compensated with a Peltier element which is connected to a temperature controller. The readout of the photodiodes is performed via a conventional source meter, Keithley 2602, for two of the photodiodes simultaneously.

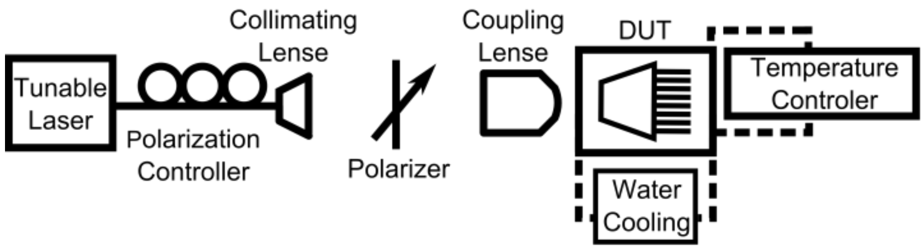

Fig. 2: Schematic of experimental setup, containing water cooling and electrical temperature control via a Peltier element

Based on the integrated photo detector array, we measured two FSRs of the AWG, displayed in Fig. 3. The FSR is 87 nm with 16 channels spaced 5 nm. Hence, the gaps in the measured figure indicate desired transitions between FSRs of the AWG. The response of the photo detectors is sufficient to resolve the pass bands of the AWG over 180 nm, indicating an average insertion loss of approximately 5 dB for the AWG. The reference signal decays towards the edge of the measurement range due to reduction of the laser power and the photo diode response. The simulated transmission, obtained via the Beam Propagation Method, is calibrated using the detector response and matched to the central FSR with good agreement. The measured pass bands are marginally wider than the simulated, indicating a wider receiver spacing than the design value. The noise floor in the figure is caused by the noise level of the photo detectors and their readout. The dark current of all photo-detectors has been measured with an average value of 21 nA with a standard deviation of 5 nA.

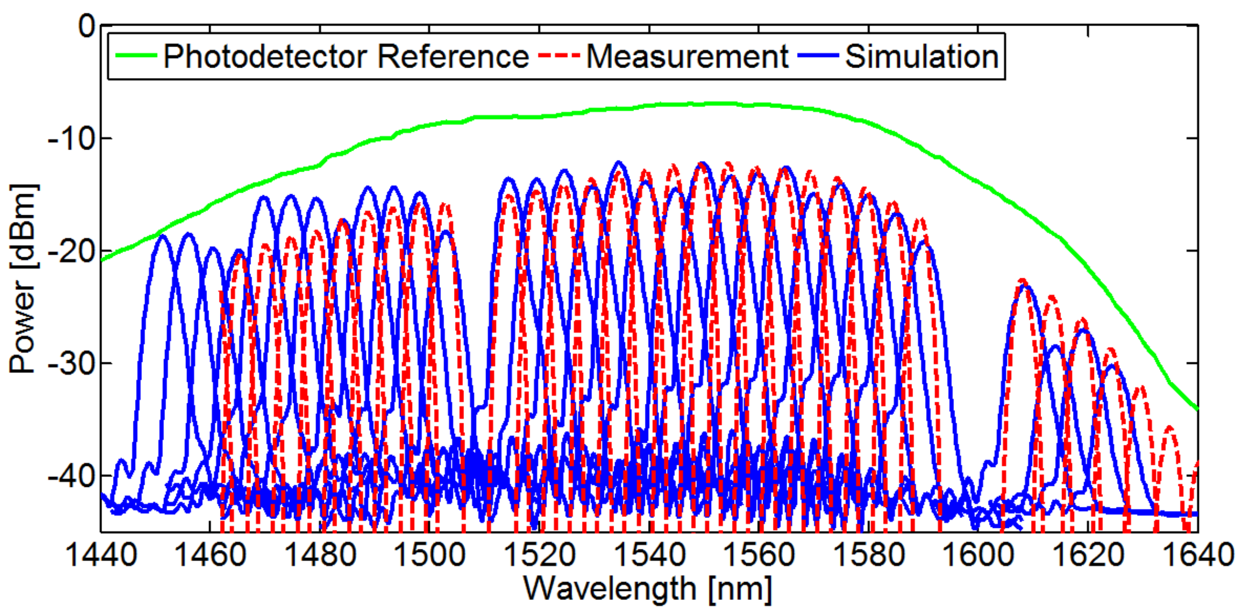

Fig. 3: Integrated measurement of 16-channel AWG via detector array.

The sensitivity of the system is tested by using two inverted slopes of adjacent AWG channels, as indicated in Fig. 4 (a). The laser wavelength is set to match the pass band intersection for a time period of 5 s, after which the wavelength is tuned discretely by 5, 10 or 20 pm. The detectors are analyzed in steps of 0.1 s without averaging. The wavelength change is expressed using the normalization $(P_1-P_2)/(P_1+P_2)$, where P_1 and P_2 are the powers on the photo detectors. Typical results are displayed in Fig. 4(b). Wavelength steps of a few pm can be clearly distinguished. The resolution limit is given by the standard deviation of the measured signal over time. We measure a typical standard deviation of 0.7 pm over a 10 s period. Further reduction of this value can be expected for a packaged device which can suppress further external influences present in the experimental setup.

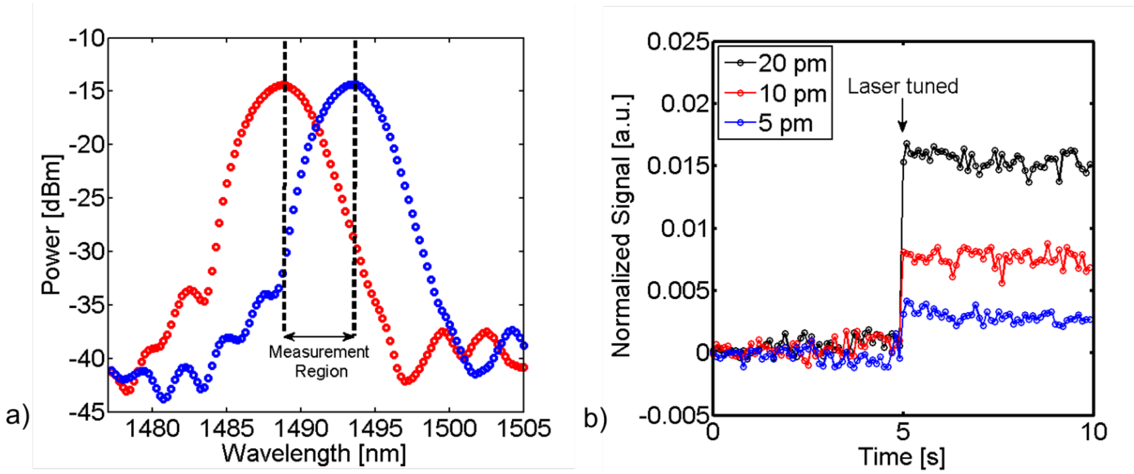

Fig. 4: Integrated measurement of two adjacent AWG pass bands, with indicated wavelength measurement region (a), 5, 10 and 20 pm wavelength steps measured at the crossing point of the AWG channels (b)

4. Conclusion

We fabricated a wavelength interrogator circuit based on a 1x16 AWG connected to an array of photo detectors. By evaluating the photocurrent variation in detectors connected to two adjacent AWG channels, we were able to clearly measure 5 pm changes in the wavelength of a tunable laser. The standard deviation over a measurement period of 10 s is 0.7 pm. Considering the spectral periodicity of the AWG, the same circuit can be potentially applied over an operating range of 180 nm.

5. Acknowledgements

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6. References

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