Nanoscale photonic dosimetry and calorimetry

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The last few decades have witnessed an exponential growth in photonics, driven in part by improvements in micro-electronics fabrication techniques and by increasing adoption of photonics components by the telecommunications industry. As a result, a wide variety of photonic-based devices have been recently proposed and developed.[1,2,3,4] These photonic sensors are particularly valuable due to their micro-/nanoscale footprint, ultra-high sensitivity, low power consumption, and tolerance to harsh environmental variables. One potential application of photonic sensors is ionizing radiation dosimetry. At present, primary standards for absorbed dose are based on large (m^3) water calorimeters used to link the absorbed energy from a large uniform radiation beam to the temperature rise in a ~0.5-mm sized thermistor probe. The realization of this standard requires radiation-beam uniformity on the order of centimeters. On the other hand, rapidly evolving medical and industrial applications are demanding a deployable solution capable of detecting ionizing radiation on a millimeter to micrometer scale. To address industry demand, National Institute of Standards and Technology (NIST) has recently started a program to develop the next generation radiation dose primary standards. The new proposed standard, built on a nano-photonic chip, will leverage nano-photonics and frequency metrology to provide a e field-deployable solution. Our radiation sensors are based on high-Q silicon photonic resonators such as ring resonators and photonic crystal cavities (PhCC) (Figure 1). We have recently demonstrated[5] that these sensors can withstand 1 MGy (1 Gy = 100 rad) absorbed dose in ca. 1 MeV gamma- and electron-beams with negligible degradation device performance. In this presentation we will give an overview of the NIST photonic dosimetry program and its most recent developments. We will explain the design, nanofabrication, packaging and interrogation of our devices. We will also show our preliminary results (Figure 2) on real-time photonic calorimetry measurements in on/off cycles of the electron beam provided by a Van de Graaff accelerator at a nominal dose rate of 1 kGy/min. Comparison of the device response with the output of finite-element modelling of heat transport and dose measurements obtained by co-irradiated alanine pellets (analyzed via EPR) will also be discussed.

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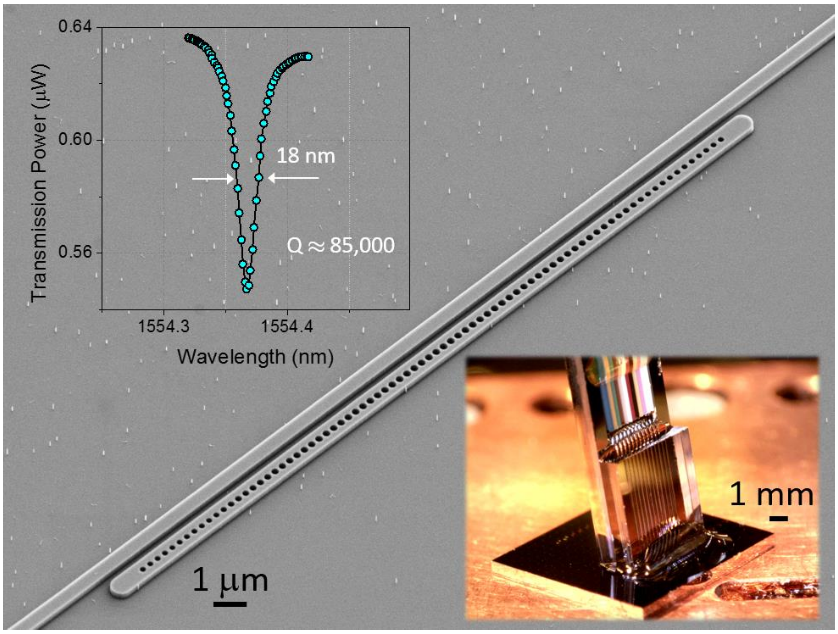

Figure 1: Silicon photonic crystal cavity (PhCC) radiation sensor: SEM image of silicon photonic nanobeam cavity radiation senor. The device is fabricated from silicon-on-insulator substrate with 220 nm thick device layer. The upper insert shows the resonant absorption peak of the sensor at 27 °C. The lower insert shows the packaged photonic chip.

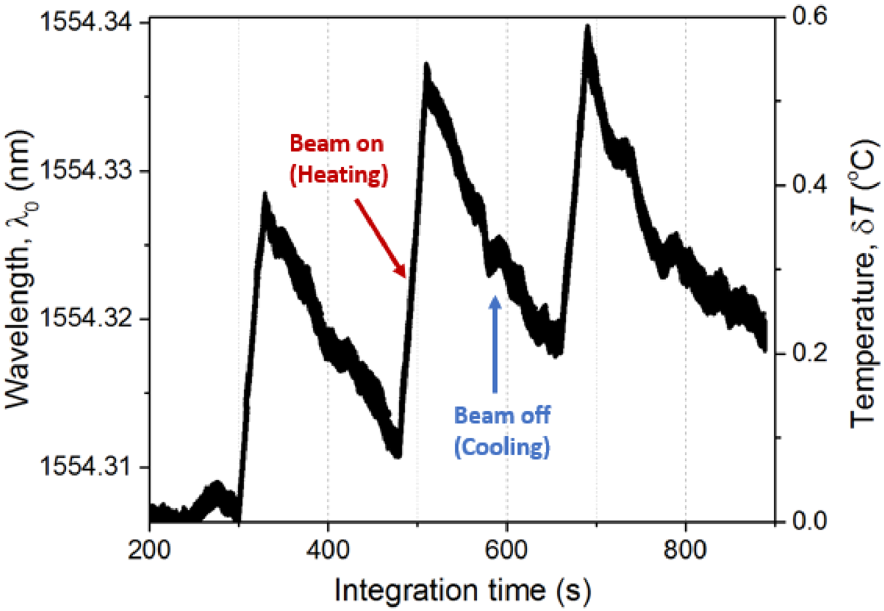

Figure 2: E-beam radiation response of PhCC sensor: Resonance wavelength response in on/off electron beam provide by a Van de Graaff accelerator.