Photon Counting Detector as a Mixer with Picowatt Local Oscillator Power Requirement

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At the current stage of the heterodyne receiver technology, great attention is paid to the development of detector arrays and matrices comprising many detectors on a single wafer. However, any traditional THz detector (such as SIS, HEB, or Schottky diode) requires quite a noticeable amount of Local Oscillator (LO) power which scales with the matrix size, and the total amount of the LO power needed is much greater than that available from compact and handy solid state sources. Substantial reduction of the LO power requirement may be obtained with a photon-counting detector used as a mixer. This approach, mentioned earlier in [1,2] provides a number of advantages. Thus, sensitivity of such a detector would be at the quantum limit (because of the photon-counting nature of the detector) and just a few LO photons for the mixing would be required leading to a possible breakthrough in the matrix receiver development. In addition, the receiver could be easily tuned from the heterodyne to the direct detection mode without any loss in its sensitivity with the latter limited only by the quantum efficiency of the detector used.

We demonstrate such a technique with the use of the Superconducting Nanowire Single Photon Detector(SNSPD)[3] irradiated by both 1.5 µm LO with a tiny amount of power (from a few picowatts down to femtowatts) facing the detector, and the test signal with a power significantly less than that of the LO. The SNSPD was operated in the current mode and the bias current was slightly below its critical value. Irradiating the detector with either the LO or the signal source produced voltage pulses which are statistically evenly distributed and could be easily counted by a lab counter or oscilloscope. Irradiating the detector by the both lasers simultaneously produced pulses at the frequency f_m which is the exact difference between the frequencies at which the two lasers operate. $f_m$could be deduced form either counts statistics integrated over a sufficient time interval or with the help of an RF spectrum analyzer.

In addition to the chip SNSPD with normal incidence coupling, we use the detectors with a travelling wave geometry design [4]. In this case a niobium nitride nanowire is placed on the top of a nanophotonic waveguide, thus increasing the efficient interaction length. Integrated device scheme allows us to measure the optical losses with high accuracy. Our approach is fully scalable and, along with a large number of devices integrated on a single chip can be adapted to the mid and far IR ranges.

This work was supported in part by the Ministry of Education and Science of the Russian Federation, contract no. 14.B25.31.0007 and by RFBR grant # 16-32-00465.

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