Frequency Division Multiplexing with Superconducting Tunnel Junctions as Rectifiers and Frequency Mixers

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The number of pixels in transition edge sensor (TES) imaging arrays is currently limitedby the complexity of the read-out scheme. The large wire count from the 300Kbiasand read-out electronics to the cryogenic detectors causes engineering problems associatedwith EMI and thermal design. For the read-out of TES detector arrays several read-out schemes exist. In this paper we focus on the frequency-division multiplexing (FDM) read-out [2]. Within FDM N channels of M TES pixels are operatedunder AC-bias and each pixel within a channel is operated at a unique frequency. Thefrequency selection of a pixel is achieved with a high-Q (superconducting) LC filter,located close to the pixel. With an AC-biasing frequency comb of M frequencies, Mpixels can be biased simultaneously. A DC-SQUID is used for the simultaneous readoutof M pixels. DC-SQUIDs need DC currents and DC flux-offsets and therefore aredifficult tomultiplex (separatewires are needed for each DC-current). Furthermore theSQUID amplifier has a limited dynamic range. The multiplexing factor M of currentstate-of-the-art SQUID devices is limited to a few tens to hundred, where feedback isapplied to the SQUID to improve the dynamic range. For large scale arrays with Kpixels, N=K/M parallel channels with each a separate SQUID amplifier chain haveto be used.In order to significantly reduce the wiring between the 300K electronics and thecryogenic level, we propose to apply an extra layer of frequency multiplexing forthe N channels, by frequency up- and down-conversion in the warm electronics andthe use of superconducting tunnel junction (SIS) frequency converters and RF-to-DCconverters at cryogenic temperatures.

In the paper we describe initial experimental results of the components that are part of a cryogenic multiplexing scheme. We have designed and characterized a six-channel cryogenic RF-to-DC multiplexing scheme consisting of commercial discrete components, in combination with a planar superconducting channelizing filter and SIS junctions. With the current multiplexer we can control six DC-bias currents with a single pair of wires, and one coaxial cable running from 4K to 300 K. The individual DC-current amplitudes are controlled by adjusting the RF power of individual frequencies in a frequency comb of 6 frequencies. The frequency span of the comb is 4-6 GHz.

As an initial demonstration we have connected the RF-to-DC converter output to the feedback coil of a DC SQUID. With this set-up we were able to control the feedback flux in the SQUID by adjusting the RF power and we could actually also demonstrate an RF controlled flux-locked loop of a DC-SQUID.