Composite Reflective/Absorptive IR-Blocking Filters on Metamaterial Anti-reflection Coated Silicon

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Infrared blocking filters are crucial for controlling the radiative loading on cryogenic systems and optimizing the sensitivity of bolometric detectors in the far-IR. Currently used quasi-optical filters commonly realized by stacking multiple layers of frequency selective surfaces, their stop-band is limited by the substrate thickness and minimum feature size, and they are subject to localized heating due to their typical substrates having low thermal conductivity. Absorptive filters using nylon heat up and reradiate in band. Recently, absorptive filters based on alumina have been proposed and used with success. The properties of these filters depend on the intrinsic properties of the alumina used, are sensitive to the sintering process, and are difficult to antireflection coat. We present a new approach to filters based on a combination of patterned frequency selective structures and a thin (50 micron thick) absorptive composite based on powdered Reststrahlen materials. This combination reflects >95% of the incoming light reducing loading and absorbs > 99.7% of the remaining light from a 300K blackbody. This allows for a reduction in the IR loading to negligible levels in a single cold filter. These filters are fabricated on silicon substrates which provide excellent thermal transport laterally through the filter and ensure that the entire area of the absorptive filter stays near the bath temperature. A metamaterial antireflection coating cut into these substrates reduces in band reflections to below 1%, and the in band absorption of the absorptive powder mix is below 0.2% (for signal bands below 500 GHz). This new filter minimizes the loading on the cryogenic stage, and limits in band re-radiation to negligible levels. In the future these filters could be integrated into silicon lenses to provide excellent filtering at a negligible cost increase.