Passive superconducting circulator on a chip

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A microwave circulator that is compatible with on-chip superconducting devices is a key element for scale-up of superconducting circuits. The existing attempts to incorporate circulators on a superconducting chip involve either external driving that requires extra microwave lines or a strong magnetic field that would compromise superconductivity. Here we report the first realisation of a passive on-chip circulator which is made from a superconducting loop with three Josephson junctions and is tuned with only DC control fields. Our experimental results show non-reciprocal behaviour and reveal that the device operation is limited by imprecision in fabrication of Josephson junctions as well as quasiparticle tunneling. By improving the fabrication precision and utilising the known methods of protection from quasiparticles, we expect the Josephson-loop circulator to be ubiquitous in superconducting circuits, addressing the integration flaws of commercial circulators.

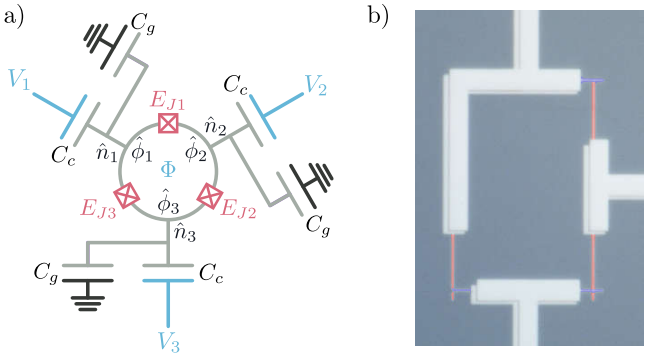

Figure 1: a) Lumped-element circuit of the passive on-chip superconducting circulator. The device is a superconducting loop that is interrupted by three Josephson junctions to form three superconducting islands. The islands are biased by three gate charges and coupled to the external ports by interdigitated capacitors. The superconducting loop is threaded by an external flux. b) False coloured optical microscope image of a fabricated loop. The three islands are white. The Josephson junctions are formed by overlapping two layers of aluminium shown in purple and red with a layer of aluminium oxide in between.