Concept for Utilizing Full Areas of STJ Photodetector Arrays

Also, cross-talk among pixels and the number of contacts would be reduced.

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A method of designing improved monolithic planar arrays of superconducting tunnel junctions (STJs) for use as photodetectors has been conceived. These arrays would be suitable for detecting images at low light levels. They are for operation in the individual-photon-counting regime; they are used not only to detect the arrival of individual photons but also to measure the individual photon energies. As such, the STJ arrays would be compact sensors that would perform the functions now performed by bulkier equipment in the form of photomultipliers and spectrometers. Eventually, it should be possible to use STJ arrays for such demanding applications as simultaneous imaging and spectroscopy of faint astronomical objects.

Usually, an STJ photodetector contains three superconductors with different superconducting energy gaps. Photons in the energy range of interest are absorbed in the superconductor with the intermediate energy gap; this superconductor and the one with the lowest energy gap are separated by a layer of electrical insulation thin enough that photoexcited quasi-particles can tunnel (in the quantum-mechanical sense) through it. Together, the intermediate- and lowest-energy-gap superconductors and the insulating layer between them constitute the detector junction. The superconductor with the highest energy gap is used for wiring to the other two superconductors. In a typical previously developed STJ array, separate electrical connections are made to each photodetector (see Figure 1).

Even an abbreviated explanation of the present method and the ways in which it differs from older STJ-array-design methods would greatly exceed the scope of this article because it would unavoidably include complex and interdependent details of the physics and the fabrication of STJ devices in general. For the purpose of this article, it must suffice to summarize the major distinguishing features:

- In the previously developed STJ photodetector arrays, pixels are separated by small gaps, through which photons can pass undetected. These gaps can amount to significant fractions of total detector areas; in other words, overall quantum efficiencies are lower than they would be if full detector areas were utilized. In STJ arrays according to the present method (see Figure 2), the gaps between pixels would be either negligibly small or entirely absent; in other words, full detector areas would be utilized, thereby maximizing quantum efficiencies.
- In a typical previously developed STJ array of m rows and n columns, the number of electrical contacts necessary for individual biasing and readout of all pixels

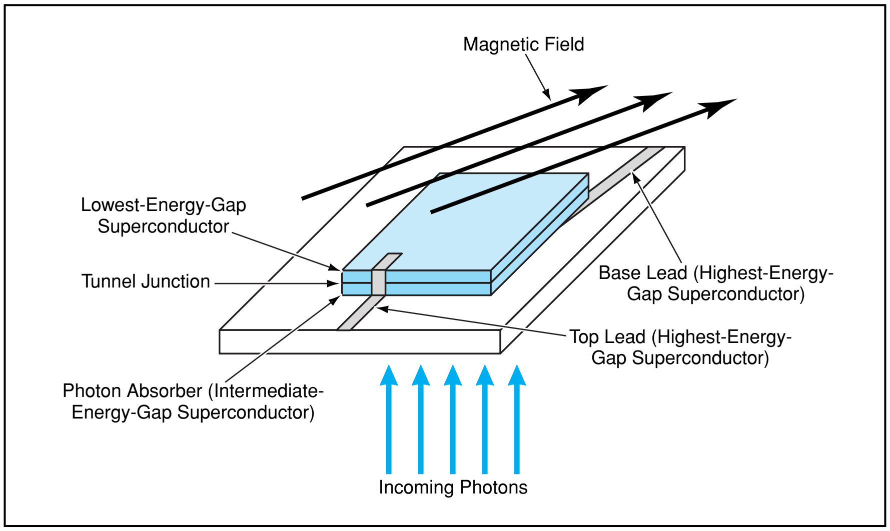

Figure 1. A **Typical STJ Photodetector** contains a tunnel junction between an intermediate- and a low-energy-gap superconductor. The electrical connections to the device are made via the base and top leads, which are made of a higher-energy-gap superconductor.

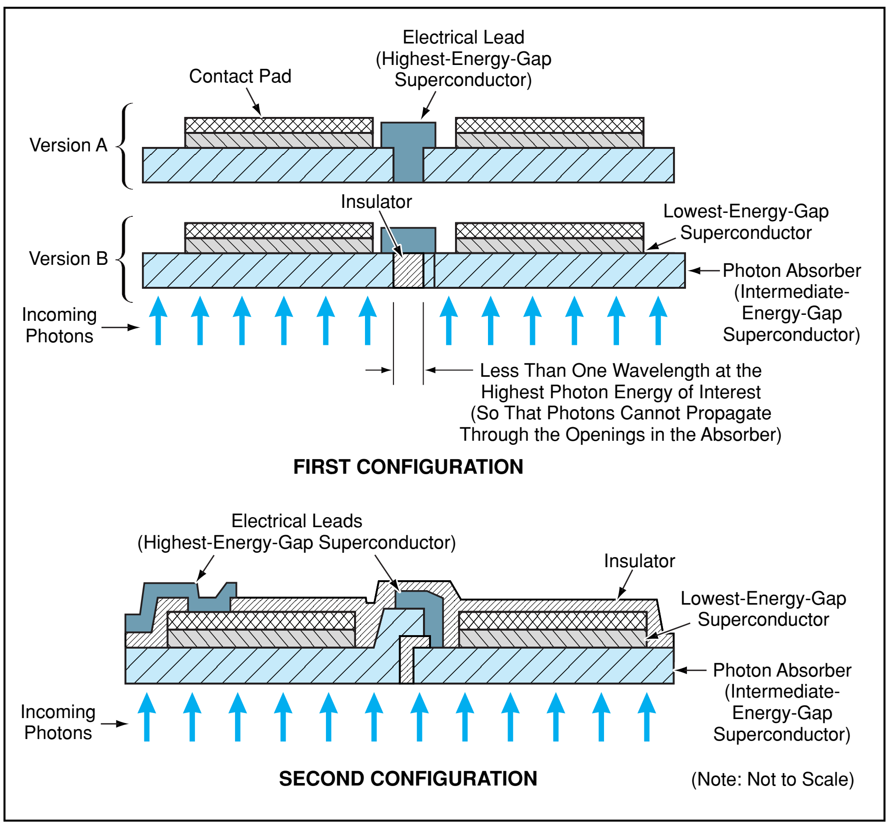

Figure 2. **Two Adjacent Pixels** of an STJ photodetector array according to the present method could be fabricated in either of two basic alternative configurations. In both configurations, the structure would behave like a solid ground plane for incident radiation at frequencies from dc up through hundreds of gigahertz, yet would present all (in the second configuration) or nearly all (in the first configuration) of its area for absorption of photons in the energy range of interest.

is 2mn because two contacts are needed for each pixel. In an STJ according to the present method, the number of contacts needed would be mn + 1 (slightly more than half the number previously needed) because the photon-absorbing (intermediate-energy-gap) superconductors of all the pixels would be electrically tied together by the largest-energy-gap superconductor.

- Even though the full detector area would be utilized in the present method, the pixels would be electrically isolated from each other with respect to diffusion of photoexcited quasi-particles between superconductors, so that cross-talk among pixels would be suppressed.
- Unlike at least one prior method, the present method does not call for small superconducting bridges among neighboring pixels. This is an advantage in that such bridges could, potentially, constitute undesired superconductive magnetic-flux-trapping loops.

This work was done by Michael Burns of Caltech for **NASA's Jet Propulsion Laboratory**.

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