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RF SUPERCONDUCTIVITY RESEARCH AND DEVELOPMENT AT LOS ALAMOS NATIONAL LABORATORY

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Los Alamos National Laboratory is engaged in two distinct areas of rf superconductivity research and development. One program is devoted to studying the rf properties of high-temperature superconductors (HTS) and assessing their potential for accelerator-cavity applications. Our best results to date have come from $YBa_2Cu_3O_7$ films (0.8 µm) electron-beam deposited onto $LaGaO_3$ substrates. A typical surface resistance value is 0.2 ± 0.1 mΩ measured at 22 GHz and 4 K, which is only a factor of 2 - 4 higher than Nb.

A second area of rf superconductivity R&D at Los Alamos involves fabricating and testing conventional Nb superconducting rf cavities. Facilities are being constructed for polishing, cleaning, and testing both small (3-GHz) and large (805-MHz) Nb cavities. Much of our effort is being devoted to understanding the proper techniques for welding, cleaning, and handling Nb cavities, to ensure good high-field performance.

Nb cavity applications are foreseen in upgrades to LAMPF, compact free-electron lasers, and high-current cw proton linacs. A single 402.5-MHz Nb cavity (in a beam cryostat) is presently being acquired from industry to provide a momentum compactor for the low-energy pion beam at LAMPF.

HTS Research

Applications involving high-temperature superconductors (HTS) generally fall into two categories; those that require low values of surface resistance (R_s) in negligible surface magnetic fields (H_{rf}), and those that require low values of R_s in moderate to strong fields. Radiofrequency (rf) accelerating cavities demand the latter criterion. The possibility of fabricating HTS cavities that exhibit high Q-values in strong rf fields (~ few hundred oersteds) at temperatures greater than LHe (4 K) has motivated many researchers to investigate the electrodynamic properties of these unique materials.[1-3]

We have employed several cavity types to investigate R_s of HTS materials. A 3-GHz Nb cavity (TM_{010} fundamental mode) operating at 4 K has been used to measure R_s of bulk ceramic specimens. For polycrystalline $YBa_2Cu_3O_7$ (YBCO) we have attained R_s values near 0.1 mΩ at 4 K (3 GHz), which is two orders of magnitude higher than Nb. Much lower values have been obtained from oriented thin films.[4] Utilizing 22-GHz Cu and Nb cavities (TE_{011} fundamental mode), we have measured R_s of several YBCO films (typically 0.8 μm thickness) which were electron-beam deposited onto 1" LaGaO3 substrates. Typical R_s values obtained at 22 GHz and 4 K are 0.8±0.1 mΩ, with the best value being 0.2±0.1 mΩ.

The surface resistances of both 1" and 1.5" Tl-Ba-Ca-Cu-O (TBCCO) polycrystalline films that have been magnetron-sputtered onto yttria-stabilized zirconia (YSZ) have also been measured. In addition to the 22-GHz Cu cavity (1" films), we have also used an 18-GHz Cu cavity (1.5" films) for these measurements. A typical R_s

value for a 1" TBCCO film measured at 12 K and 22 GHz is 5 ±2 mΩ; this value increases to ~50 mΩ at 77 K. As shown in Fig. 1, the value at 4 K is only slightly lower than Cu. The 1.5" TBCCO films are characterized by R_s values that are approximately equal to Cu at 4 K. By orienting the crystalline axes of these films we expect to achieve lower R_s values.

For rf cavity applications it is necessary to achieve low values of R_s in the presence of moderately high surface magnetic fields. A typical accelerating electric field of 5 MV/m corresponds to H_{rf} ~ 300 - 500 Oe. R_s vs. H_{rf} measurements on single crystals, laser-ablation produced films, and grain-aligned bulk ceramics indicate that R_s becomes very large for H_{rf} > 90 Oe.[5] These measurements were made by placing the samples on a sapphire pedestal inside an evacuated cavity. This arrangement does not allow the rf-generated heat to be readily dissipated, and, consequently, the value of H_{rf} where R_s rapidly increases may not be the intrinsic value. Similar measurements on long cylindrical rods of YBCO immersed in LN_2 or LHe show that field values of ~640 Oe can be achieved without destroying superconductivity.[6] Preliminary measurements of R_s vs. H_{rf} on our YBCO films indicate that R_s approaches its normal-state value for H_{rf} > 20 Oe. Further measurements on YBCO and TBCCO films are awaiting construction and testing of an 18-GHz Nb cavity.

Conventional Superconductor Research

A second area of rf superconductivity research and development at Los Alamos involves fabricating and testing conventional Nb rf cavities. Facilities are being constructed for polishing, cleaning, and testing both small (3-GHz) and large (805-MHz) Nb cavities. Progress to date includes installation of a clean room and a clean-water system, design of a chemical-polishing system, installation of test cryostats, and fabrication of four 3-GHz cavities, which are presently undergoing initial high-field testing. Preliminary results for the first cavity showed that an electric field of 8 ±1 MV/m could be achieved in the cavity before it suffered a superconducting quench, presumably due to surface defects. The significance of this result lies not in the value of electric field attained (which is above the industry standard value of 5 MV/m), but in the fact that this represents the first superconducting Nb cavity which was fabricated, cleaned, and tested at Los Alamos National Laboratory, and thus represents our entry into this high-technology arena.

Two 805-MHz Nb cavities have been formed and e-beam welded and are awaiting chemical cleaning; these are shown in Fig. 2. Cavities of this particular frequency are of interest because they represent the operating frequency of the Los Alamos Meson Physics Facility (LAMPF) accelerator. Future upgrades to this facility would probably involve installation of superconducting cavities, and consequently we would like to have the on-site capability to fabricate and test such devices. Presently, however, much of our experimental effort is devoted to understanding the proper techniques for welding, cleaning, and handling Nb cavities to ensure good high-field performance.

Applications

Niobium cavity applications are foreseen in upgrades to LAMPF, compact free-electron lasers, and high-current cw proton linacs. A single 402.5 MHz Nb cavity (in a beam cryostat) is presently being acquired from industry to provide a momentum compactor for the low-energy pion beam at LAMPF. The basic idea of this application is to take the pion beam at the achromatic focus of the LAMPF low-energy pion (LEP) channel and inject it into the superconducting cavity at zero degrees phase angle so that it does not undergo any net acceleration. Particles at the early part of the pion bunch are decelerated while those arriving at a later time are accelerated. Because there is a correlation between time and energy, the net result of this "SCRUNCHER" (superconducting rf unit for changing energy resolution) is to compress the energy spread of the pion beam as shown in Fig. 3. This yields a factor of five improvement in the beam flux per MeV of energy. Currently the energy spread is controlled by a set of jaws which accept only a small momentum bite. Installation of the SCRUNCHER cavity will allow us to take the full acceptance of the channel (±2% in momentum) and compress it to ±0.4%.

The SCRUNCHER is being built by INTERATOM using standard technology, except that it will be pipe-cooled rather than bath cooled. It will be tested at INTERATOM and, assuming that it meets technical specifications, will be delivered to LAMPF where it will be installed at LEP.

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FIGURE CAPTIONS

Fig. 1. Surface resistance of TBCCO and YBCO. 1" and 1.5" samples are measured at 22 and 18 GHz, respectively. Cu and Nb are shown for reference.

Fig. 2. 805-MHz Nb cavities fabricated at Los Alamos.

Fig. 3. Schematic illustration of pion beam compression as anticipated from installation of a superconducting 402.5-MHz Nb cavity at the LAMPF low-energy pion channel.

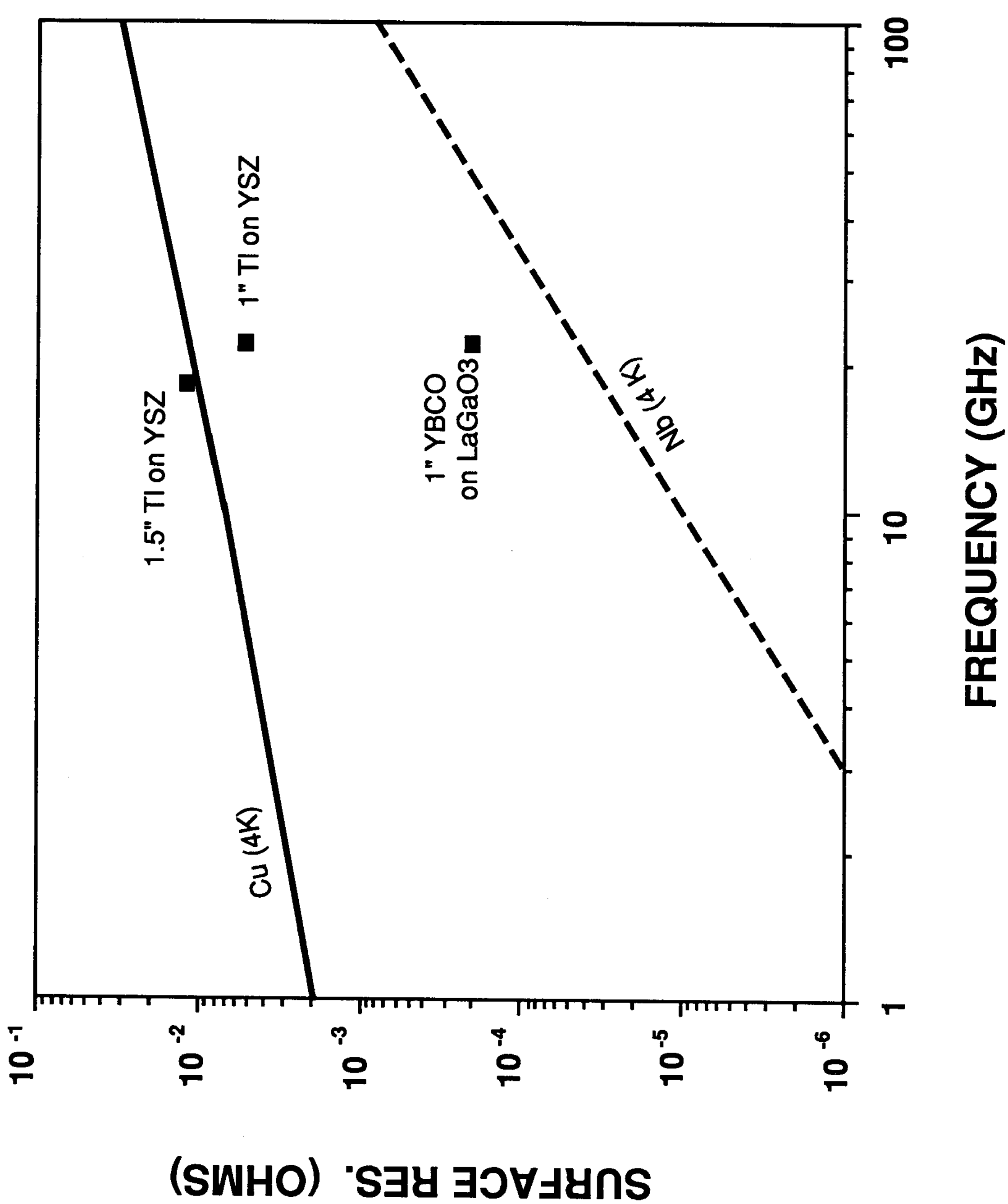

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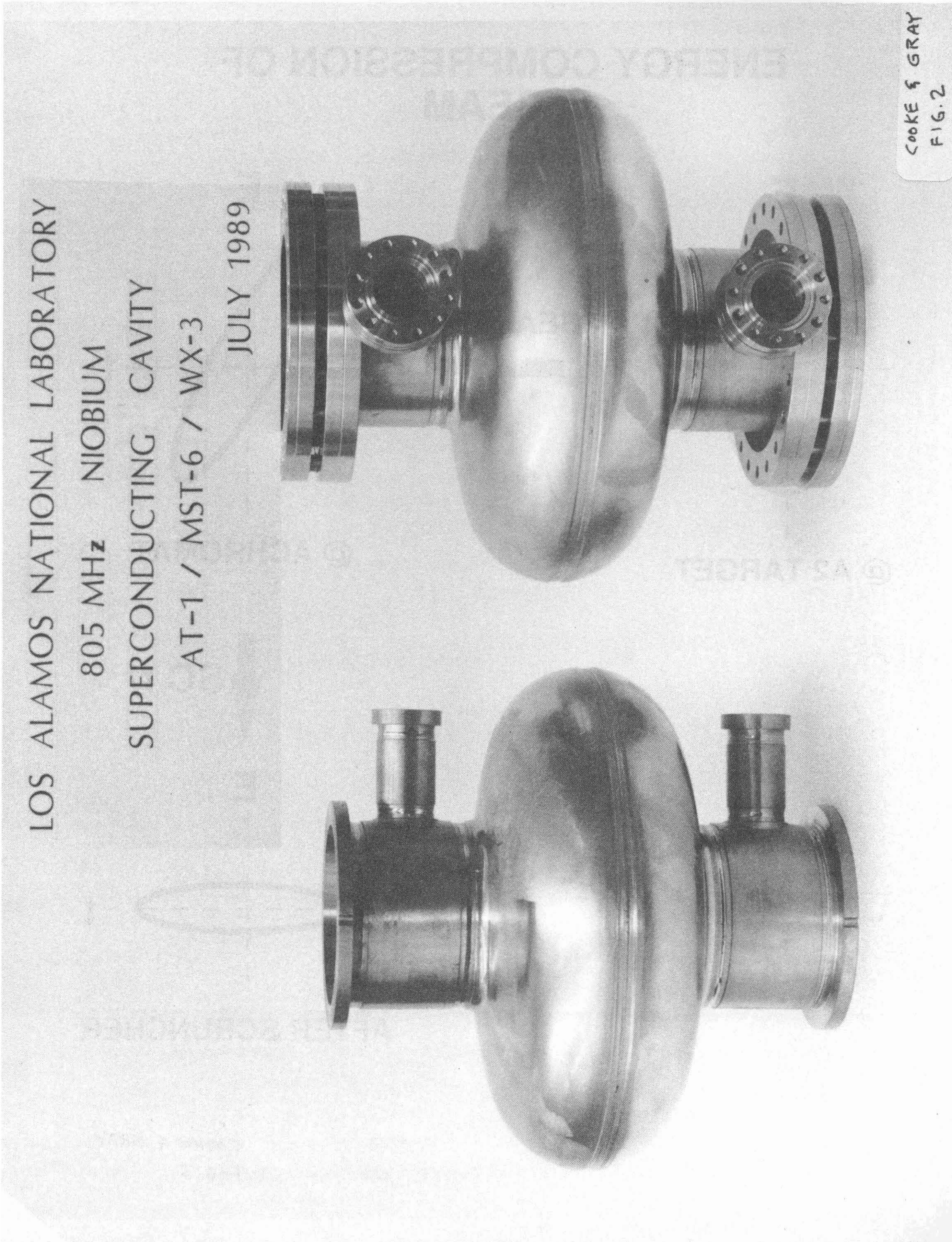
FIG. 1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805 MHz NIOBIUM
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FIG. 2

ENERGY COMPRESSION OF A BEAM

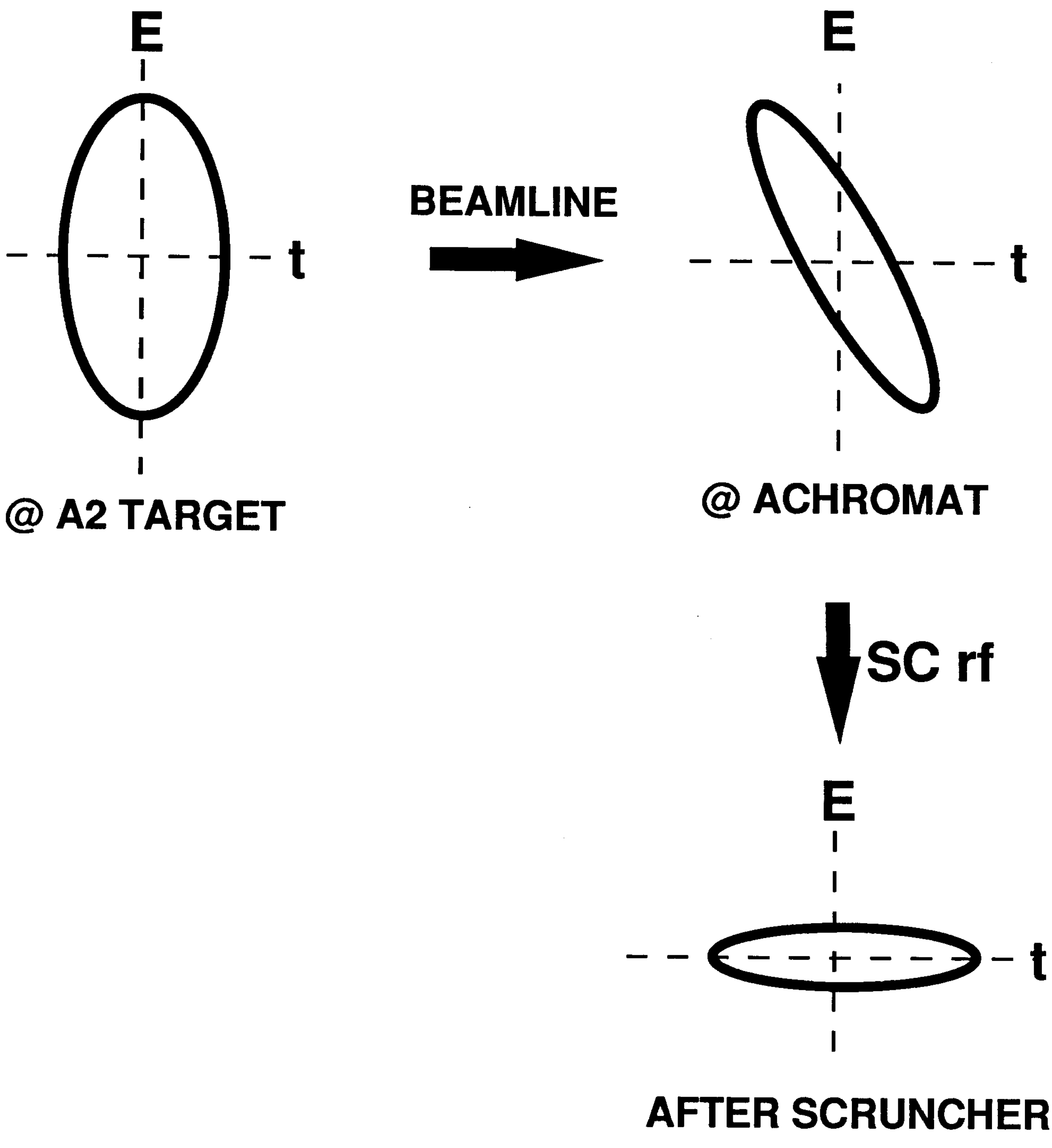

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FIG. 3