Status of RF Superconductivity at Argonne

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Introduction

Development of a superconducting (SC) slow-wave structures began at Argonne National Laboratory (ANL) in 1971, and led to the first SC heavy-ion linac (ATLAS - the Argonne Tandem-Linac Accelerating System), which began regularly scheduled operation in 1978 [1,2]. To date, more than 40,000 hours of beam-on-target operating time has been accumulated with ATLAS [3]. The Physics Division at ANL has continued to develop SC RF technology for accelerating heavy-ions, with the result that the SC linac has, up to the present, has been in an almost continuous process of upgrade and expansion [4,5]. It should be noted that that this has been accomplished while at the same time maintaining a vigorous operating schedule in support of the nuclear and atomic physics research programs of the division.

In 1987, the Engineering Physics Division at ANL began development of SC RF components for the acceleration of high-brightness proton and deuterium beams. This work has included the evaluation of RF properties of high-Tc oxide superconductors, both for the above and for other applications [6,7].

The two divisions collaborate in work on several applications of RF SC, and also in work to develop the technology generally.

SC Heavy-ion Linac

Recent development in the Physics Division has focused on a very-low-velocity ($.007 < \beta = v/c < .06$) SC linac, which, together with a source of highly-charged positive ions, forms a new positive-ion-injector (PII) for the present ATLAS heavy-ion accelerator [5,8]. ATLAS is presently injected by a 9 MV electrostatic accelerator. The PII upgrade will replace the 9 MV tandem Van de Graaff, increasing the upper mass limit of the accelerating system from iodine to uranium, and increasing the available beam current by a factor of 10 to 100.

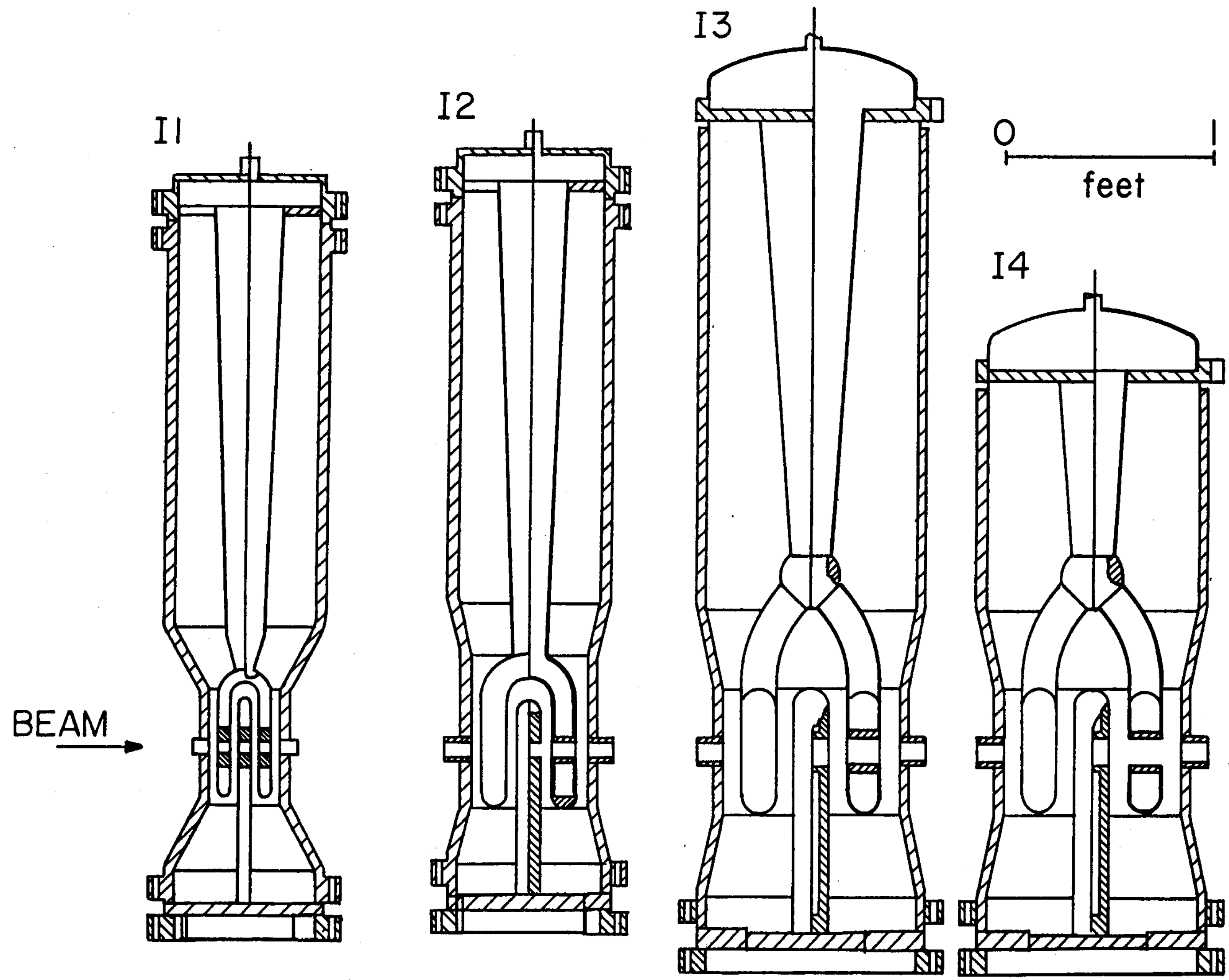

Figure 1 - Cross-sections of the 4 - gap interdigital superconducting resonators for the injector linac. The first three units operate at 48.5 MHz and the fourth at 72.75 MHz.

The low-velocity linac consists of an array of four different geometries of interdigital accelerating structure (shown in Fig. 1). This structure is formed by terminating a coaxial, quarter-wave line with a bifurcated drift-tube and counter drift-tube, thus constituting a four-gap accelerating structure [8]. Table I lists some properties of the interdigital structures, together with performance observed both off and on-line.

Table I

Some Characteristics for Four Superconducting Niobium Interdigital Accelerating Structures

Unit	Matched Velocity	Frequency	Effective Length	Accelerating Field* Off-line	On-line
I1	.009	48.5 MHz	10 cm	5.1 MV/m	4.4 MV/m
I2	.015	48.5	16.5	4.5	3.0
I3	.025	48.5	25.4	4.1	3.7
I4	.037	72.75	25.4	3.9	4.1

*For approx. 4 watts RF input to 4.6 K.

The PII system is being constructed in three phases. The first phase consists of an electron-cyclotron-resonant (ECR) positive ion source on a 350 KV open air voltage platform, and a 3 MV superconducting injector linac. Each succeeding phase will add approximately 5 MV of accelerating potential to the low-velocity linac. Completion of the third phase will enable the injection of uranium beams into the existing ATLAS superconducting heavy-ion linac. Figure 2 shows the interior of an interdigital structure prior to final assembly. Figure 3 shows the resonator array for the first cryostat module being assembled in the phase one configuration. Figure 4 shows the first cryostat module in the final assembly step.

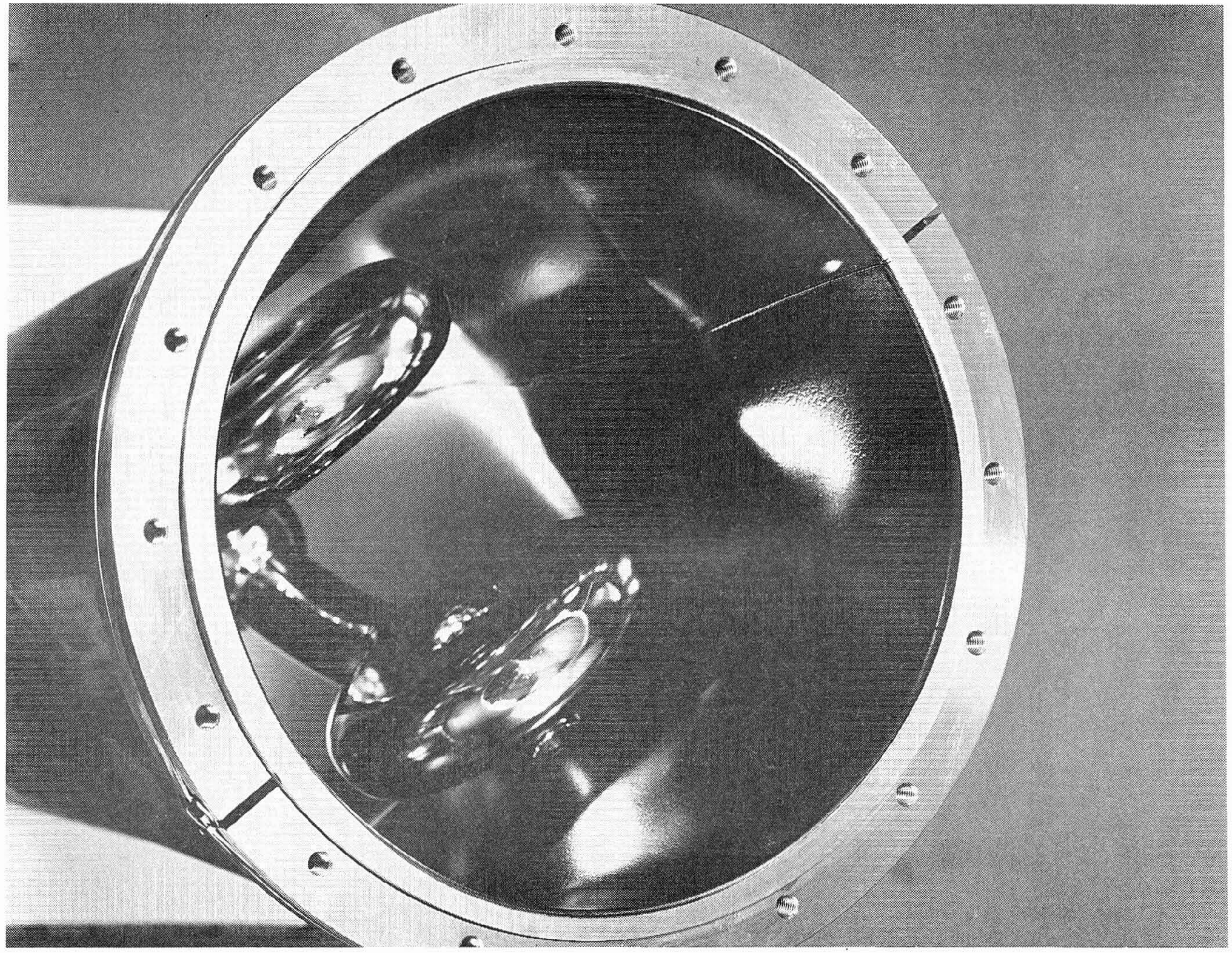

Figure 2 - Interior of an I3 type resonant cavity prior to final assembly.

The first phase of the PII was completed in early 1989 and was first operated with beam in February. Performance met design goals both in terms of accelerating voltage available and in terms of beam quality [5]. The second phase, which will add one cryostat module to the linac will be complete in early calendar 1990, and the third and final phase in 1991.

Proton Accelerating Structures

The Engineering Physics division at Argonne is developing superconducting resonant cavities for the acceleration of high-current proton and deuteron beams. Figure 5 shows several resonant geometries, niobium prototypes of which are currently under construction. The resonant frequencies of these cavities are in the range 325 - 850 MHz, and the useful velocity range from $.1 < \beta = v/c < .5$. Tests of these cavities will explore a hitherto unexamined range of frequency and velocity for application of superconducting RF. This work is more fully described in a contribution to the proceedings of this workshop [6].

RF Properties of Oxide Superconductors

The Engineering Physics Division at Argonne has a program to measure the rf properties of bulk and thick-film high- Tc superconductors as a function of temperature, frequency, and rf field amplitude. This program began as a collaborative effort with the Physics Division, but is presently being carried out independently [9,10,11]. Figure 6 shows a few of the results of this program for YBCO materials. YBCO has been observed to superconduct in rf fields as high as 640 gauss at 77 K. This work is also reported in a contribution to the proceedings of this workshop [7].

Future Work

In a collaborative effort between the Physics and Engineering Physics Divisions, an existing SC split-ring resonator is being used as a "voltage platform" to evaluate the performance of a superconducting niobium RFQ. The drift tubes of the existing split ring are being modified to add four quadrupole vanes several inches long. Tests of this structure will be performed later this year.

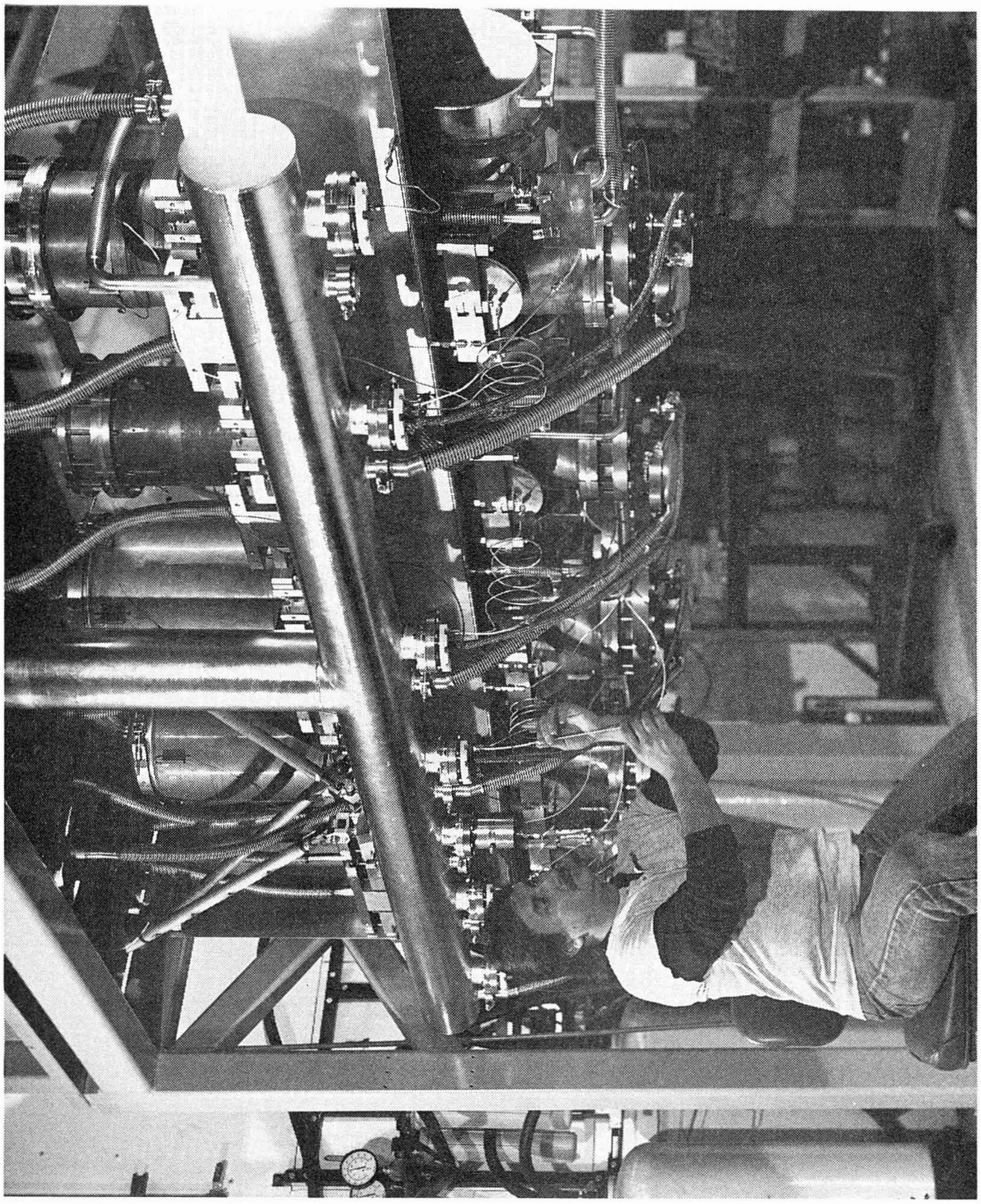

Figure 3 - Array of five resonators being assembled for the first phase of the injector system.

Both divisions expect to continue a variety of studies, frequently in collaboration, to advance the basic technology of rf superconductivity.

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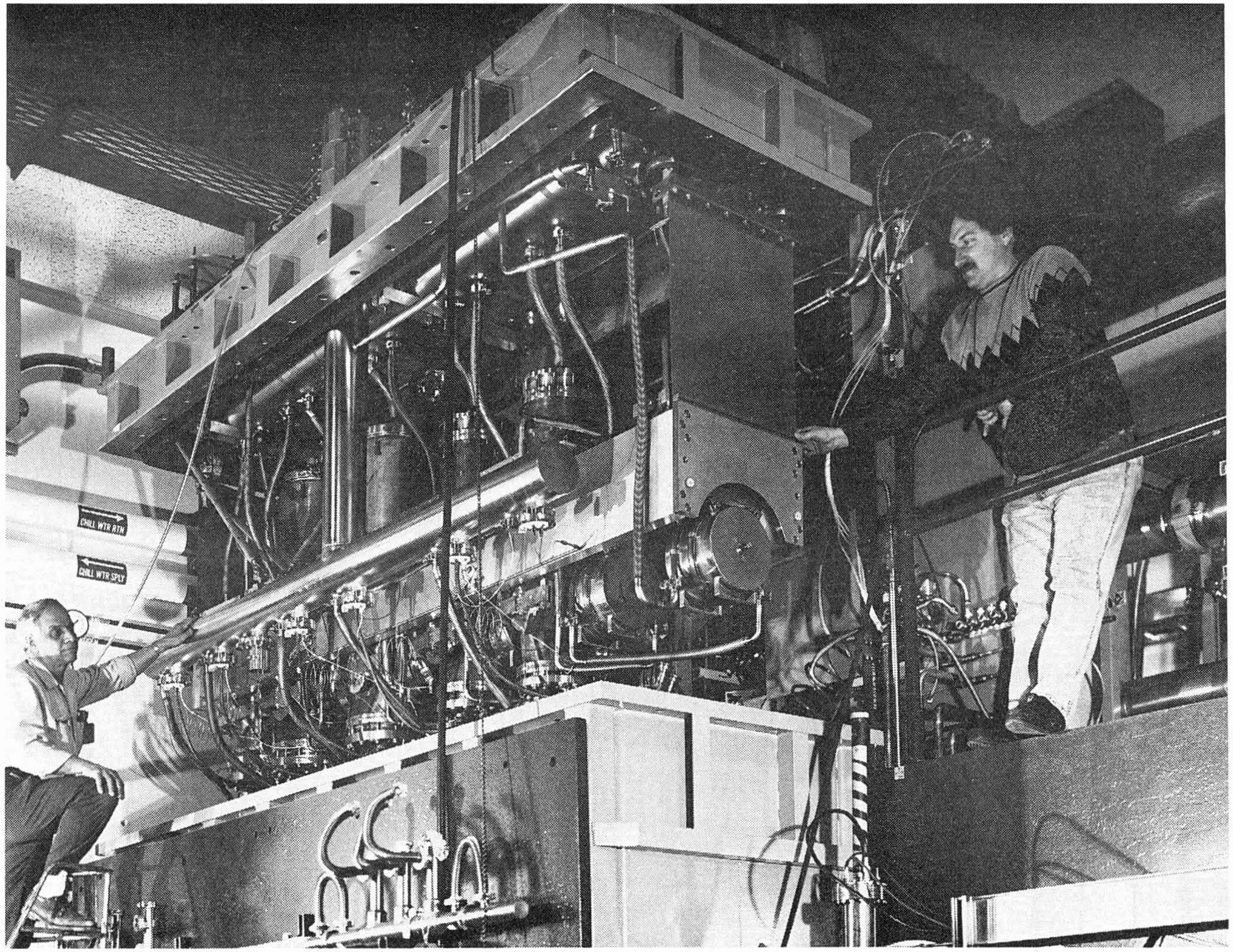

Figure 4 - Cryostat module being assembled. In the configuration shown, the linac first accelerated beam in February of 1989 and provided more than 3 MV of accelerating potential.

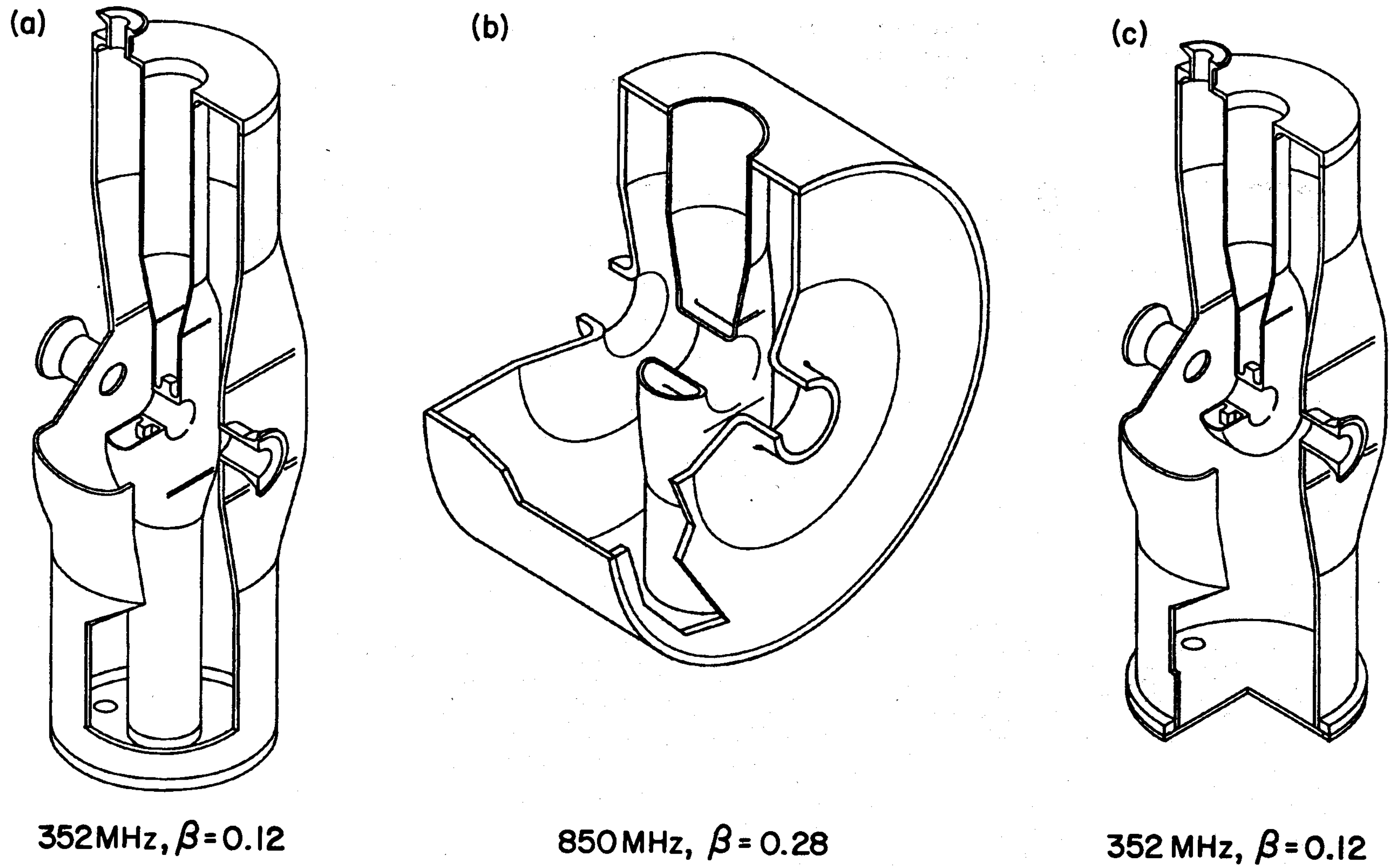

Figure 5 - Three types of resonant cavity being developed for the acceleration of light ions. All three structures are being prototyped in niobium.

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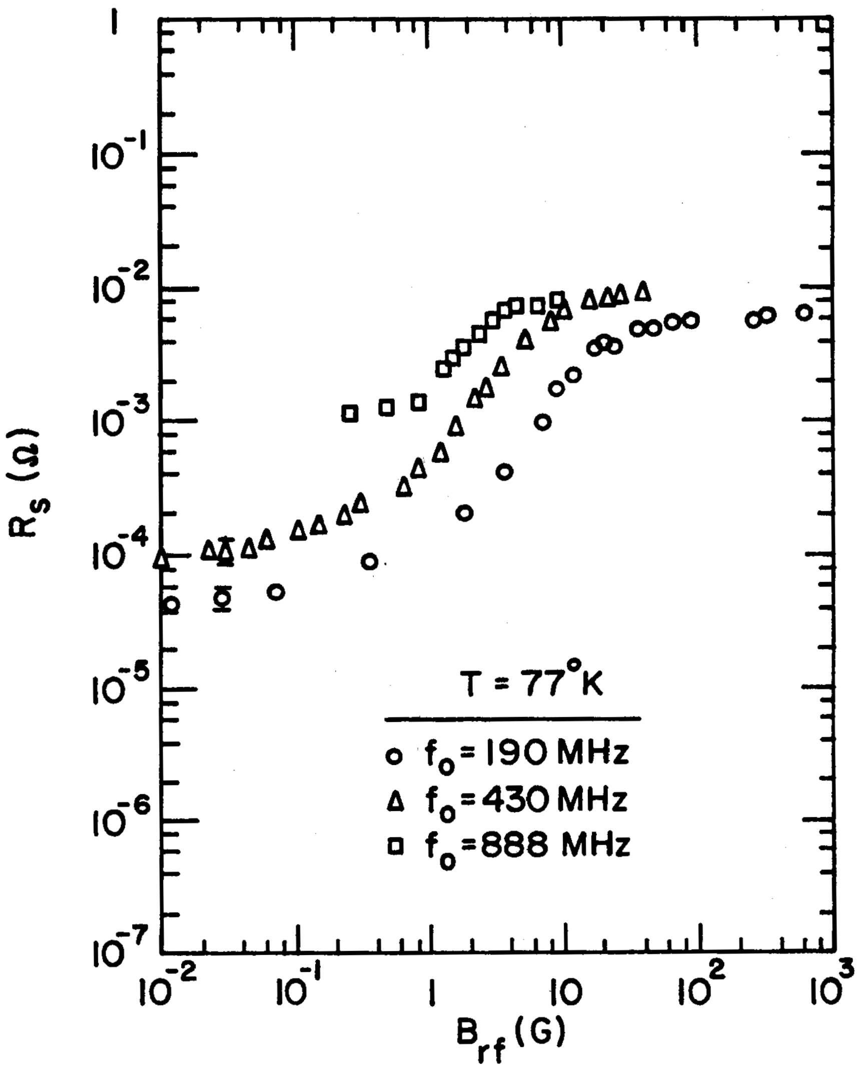

Figure 6 - Superconducting surface resistance of bulk YBCO measured at several frequencies and temperatures. A peak rf field of more than 600 gauss was obtained at 77 K.