NASA TECH BRIEF
Lewis Research Center

Technique for Refocusing, Decompressing, and Conditioning Spent Electron Beams

The problem:

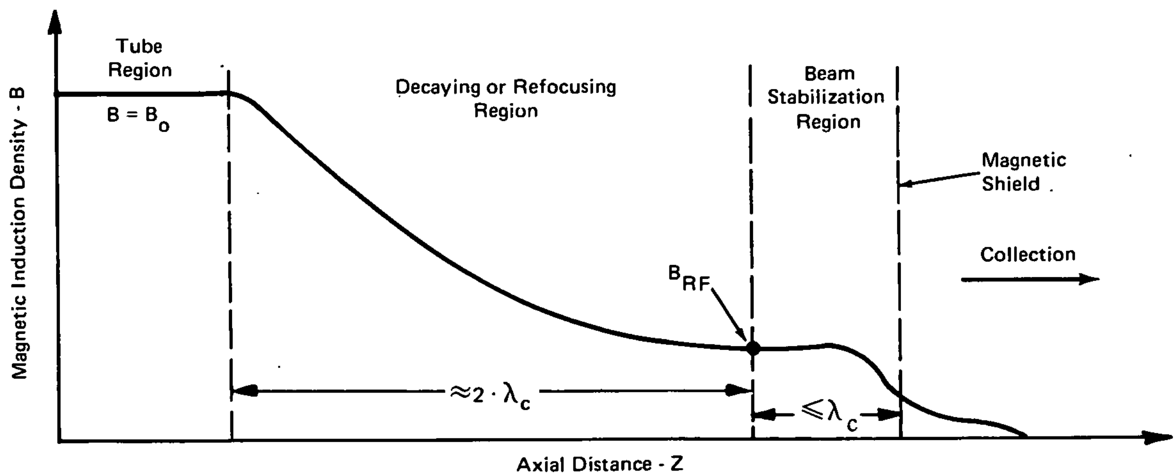
Modern space communication systems require the highest possible efficiency from transmitting devices, both to conserve primary power and to minimize the heat dissipation problem. Novel depressed collectors offer a means for achieving high overall efficiency of microwave amplifiers, but the energy recovery in such collectors depends strictly and critically on the degree of disorder in the spent electron beam. Maximum efficiency would be possible in a well-designed collector operating on a "point source" beam with only an axial velocity spread. However, real spent beams have a much more complex velocity spectrum, i.e., radial and azimuthal velocities and radial position distribution in addition to axial velocities. At high microwave frequencies (12 GHz and above) and kW power range, current densities in the beam amount to 20 to 1000 A/cm^2. After the focusing fields have been removed, such beams explode radially and are not suitable for injection into novel collectors. A substantial dilution of current densities down to a few A/cm^2 must take place before injection into novel collectors if high collector efficiency is to be achieved.

The solution:

A refocusing technique that significantly reduces transverse velocity components in the beam and dilutes the current densities to the acceptable level of a few A/cm^2.

How it's done:

As shown in the figure, the technique consists essentially of a decaying region of the focusing magnetic field over a length of not less than two cyclotron wavelengths for the average velocity group, and of a short region ($\leqslant \lambda_c$) of a constant field, called the beam stabilization region. The decaying field region dilutes the beam and reduces radial velocities. The constant field region has an action equivalent to that of a convergent magnetic lens which straightens the beam and stabilizes it at the desired radius.



(continued overleaf)

The desired magnetic field shape may be realized by arranging magnets, pole pieces, and floating pole pieces in a suitable fashion; by arranging a series of permanent coaxial magnets of different length and magnetization; or by other methods. To obtain optimum beam refocusing action, it may be necessary to adjust the rate of field decrease and the length of the stabilization region to each individual case.

The figure shows the phi magnetic induction density B plotted versus axial distance Z in an r,φ,z cylindrical coordinate system with axial symmetry. Four distinctly different magnetic field regions are characteristic of the technique. In the region designated "Tube", the magnetic field (or its amplitude in case of ppm) is constant and represents the focusing field in the tube interaction region B_o. To the right of B_o, the field magnitude decreases over a distance not less than $2\lambda_c$ down to a value of B_{Rf}. The field B_{Rf} is chosen to achieve the desired degree of decompression.

Since the equilibrium beam radius $r \propto 1/B$, and the current densities in the tube region and the collector region are known or may be selected, $B_{RF}^2 = B_o^2/$ Decompression Ratio. In passing through the refocusing region, the average beam radius increases; the current density and the transverse velocity components decrease. In the third region, designated "beam stabilization region," the beam expansion subsides and the electron stream stabilizes at the new equilibrium radius corresponding to the value B_{RF}. In this region, the transverse velocity components are minimum. The slower velocity groups drift preferentially to the edge of the beam thus providing a natural velocity-position sorting. This pre-sorting effect is very beneficial, for it reduces the degree of sorting which must be done subsequently in the collector region. Thus, higher collector efficiency is achieved than would be true without this pre-sorting because sorting consumes a certain amount of initial energy, about 10% for the slow energy classes and about 5% for the high ones. Not only is the application of depressed collectors made possible at high current densities through the refocusing scheme, but also collector efficiencies will improve by a factor of between 1.2 to 1.5 through the application of the beam refocusing technique.

Notes:

1. The technique is applicable to confined flow beams, Brillouin flow beams, solenoid focusing, permanent magnet focusing and permanent periodic magnet focusing tubes by appropriate arrangement of the pole pieces.
2. The following documentation may be obtained from:

   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)

   Reference; NASA CR-121026 (N72-11159), Refocusing of Spent Electron Beams

   Reference: NASA TN-D-6093 (N71-16585), A Novel, Axisymmetric, Electrostatic Collector for Linear Beam Microwave Tubes
3. Technical questions may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B72-10727

Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning non-exclusive or exclusive license for its commercial development should be addressed to:

Patent Counsel
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