LS-28
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Folded Coaxial Line Design for the 38.9 MHz Booster Cavity

I. Introduction

The folded-coaxial line is an alternative for the 38.9 MHz capacitively-loaded coaxial cavity suggested in LS-26[1] for the early part of the booster acceleration cycle. The folded coaxial line was investigated for two reasons: (1) in principle, less circumferential length is required by the folded coaxial line and: (2) the higher-order-mode structure is different and might be easier to damp than the capacitively-loaded coaxial cavity.

The cross section of the folded coaxial line is shown in Figure 1. The ratios of r_{mi}/r_{io} and r_{oo}/r_{mo} are the same to maintain a constant impedance between the outer and inner coaxial sections. Capacitive tuning is provided at the gap, g, by moving the tuning plate back and forth.

II. Cavity Design

The dimensions of the folded coaxial line are given in Table I and a list of the relevant parameters are given in Table II. The E-field pattern for the fundamental accelerating mode is shown in Figure 2.

The range in operating frequency of the cavity is 38.673 to 39.160 MHz, which is accomplished by moving the tuning plate by ±1.0 cm.

The cavity is excited by a coupling loop near the shorted end of the outer coaxial line. A ceramic penetration (not shown) would be used to insert the coupling loop without entering the vacuum, as was recommended for the capacitively-loaded coaxial cavity in LS-26.

The effective peak voltage including transit time is 200 kV, while the actual peak voltage is 204.7 kV. The cavity power required for 200 kV operation is 27050 W. The power distribution in the cavity with an effective gap voltage of 200 kV is shown in Figure 3.

III. Higher Order Modes (HOM)

A list of the eight lowest-frequency higher-order longitudinal modes is given in Table III. If the ratio of the HOM frequency to the fundamental frequency is near an integer value, damping of the mode with $\lambda/4$ antenna and matching resistors will be required.[2] The E-field pattern for a typical HOM is shown in Figure 4. Ideally, the location of the damping antenna should be in a location that doesn't couple to the fundamental mode. This is not possible for the field patterns shown in Figure 4. An antenna in either the outermost shell or the right side end flange will couple to the HOM, but these locations also couple to the fundamental accelerating mode. Of the two choices, outer shell or right side end flange, the outer shell is somewhat better because the E-fields of the fundamental mode are weaker in the outer shell. Nevertheless, a $\lambda/2$ trap is needed to reduce to a tolerable level coupling to the fundamental accelerating mode. The location of a damping antenna for a given mode is listed in Table III as the outer shell when possible. For those modes where the ratio of HOM to fundamental frequency is not near an integer, damping is probably not needed.

A list of the transverse modes are listed in Table IV. The location of the damping antenna for a given mode is listed in the table as either outer shell or end flange. The same criteria is used for the choice of location with the transverse modes as with the longitudinal modes. As with the capacitively-loaded coaxial cavity, transverse modes might not require damping, since a symmetrical tuning plate is used. This is the experience on the cavities for the National Synchrotron Light Source at Brookhaven National Laboratory.[3]

IV. Discussion

The folded-coaxial line is about 20% shorter than the capacitively-loaded-coaxial cavity. The shunt impedance of the folded-coaxial line is only 60% of the value for the capacitively-loaded-coaxial cavity; however, increasing the radial dimensions could increase the shunt impedance to where the two cavities have nearly the same values.

The HOM structures of the two cavities are different, but neither offers any clear advantages.

Table I
Dimensions of the Folded-Coaxial Line

Length of Outer Shell, l_o	0.892 m
Length of Inner Shell, l_i	0.807 m
Length of Middle Shell, l_m	0.792 m
Outer Radius of Inner Shell, r_{io}	0.140 m
Inner Radius of Middle Shell, r_{mi}	0.260 m
Outer Radius of Middle Shell, r_{mo}	0.320 m
Inner Radius of Outer Shell, r_{oi}	0.594 m
Inner Radius of Inner Shell, r_{ii}	0.070 m
Gap Between Tuning Plate and End of Inner Shell, g	0.06 - 0.08 m

Table II
Parameters for the Folded-Coaxial Line

Operating Frequency	38.673 - 39.160 MHz
$\int E_z \cos(k*z/\beta)dz$	200 kV
Cavity Power @ 200 kV	27050 W
Cavity Q	17079
Shunt Impedance	1.48 MΩ
TEM Coaxial Line Impedance	37.1 Ω
Peak Electric on Surface @ 200 kV Gap Voltage (38.673 MHz)	4.46 MV/m
Tuning Plate Movement	±1.0 cm

Table III
Higher-Order Longitudinal Modes

HOM Number	Frequency MHz	HOM Freq./ Fund. Freq.	R/Q ohms	Mode Damping*
0	38.673	-	86.6	-
1	114.637	2.96	24.1	EF
2	193.811	5.01	3.7	OS
3	260.801	6.74	0.4	NN
4	349.371	9.03	0.6	OS
5	397.090	10.27	3.9	NN
6	508.010	13.14	1.8	OS
7	526.271	13.60	6.1	NN
8	551.620	14.26	0.4	NN

* Mode damping is accomplished with $\lambda/4$ antennas located either on the outer shell (OS) or the right side end flange (EF). If the ratio of the frequency of the higher-order mode to the fundamental is far enough away from an integer value, mode damping is probably not necessary (NN).

Table IV
Higher-Order Transverse Modes

Mode Number	Frequency MHz	HOM Freq./ Fund. Freq.	Mode Damping*
1	167.053	4.32	OS
2	245.969	6.36	OS
3	294.214	7.61	EF
4	364.587	9.43	OS
5	403.474	10.43	EF
6	505.450	13.07	OS

* Mode damping is accomplished with $\lambda/4$ antennas located either on the outer shell (OS) or the right side end flange (EF).

References

1. R. L. Kustom, 38.9 MHz Capacitive-Loaded Coaxial Cavity Design for the Booster, 6 GeV Light Source Note, LS-26, 6/20/85.

2. Norman Fewell and Zhou Wen, Higher Order Mode Damping in the NSLS Accelerating RF Cavities by the Use of Damping Antennae, to be published in the 1985 Particle Accelerator Conference Proceedings, May 13-16, 1985, Vancouver, B.C.

3. Norman Fewell, private communication

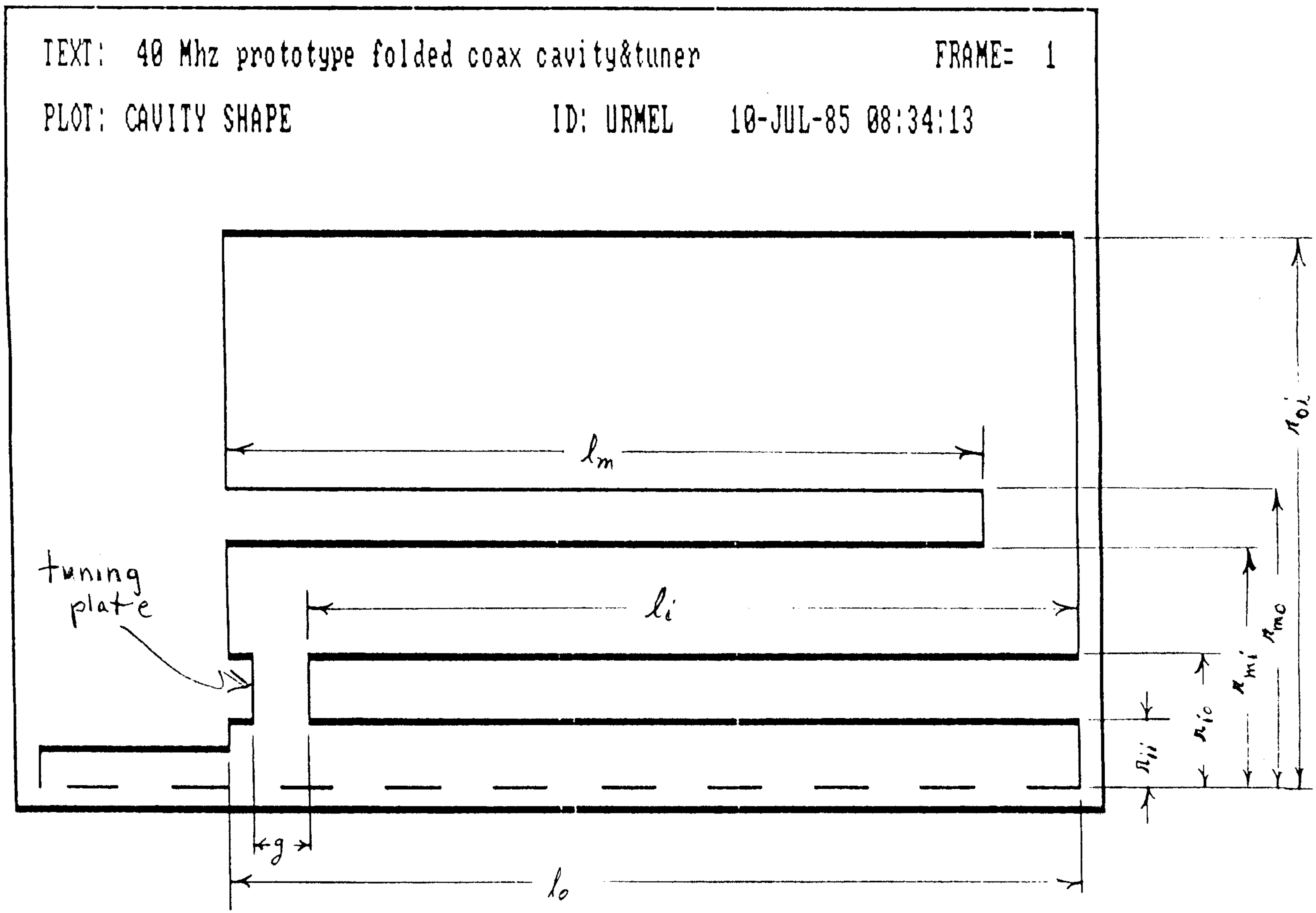

Figure 1. Cross-sectional view of the folded-coaxial line

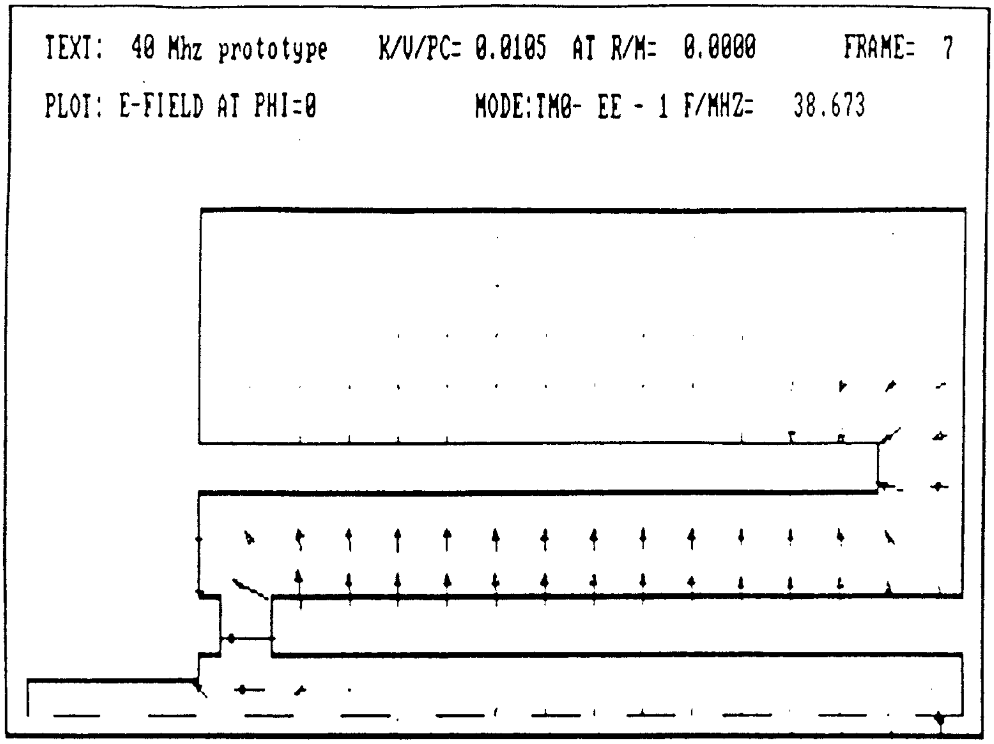

Figure 2. E-field pattern for the fundamental accelerating mode of the folded-coaxial line

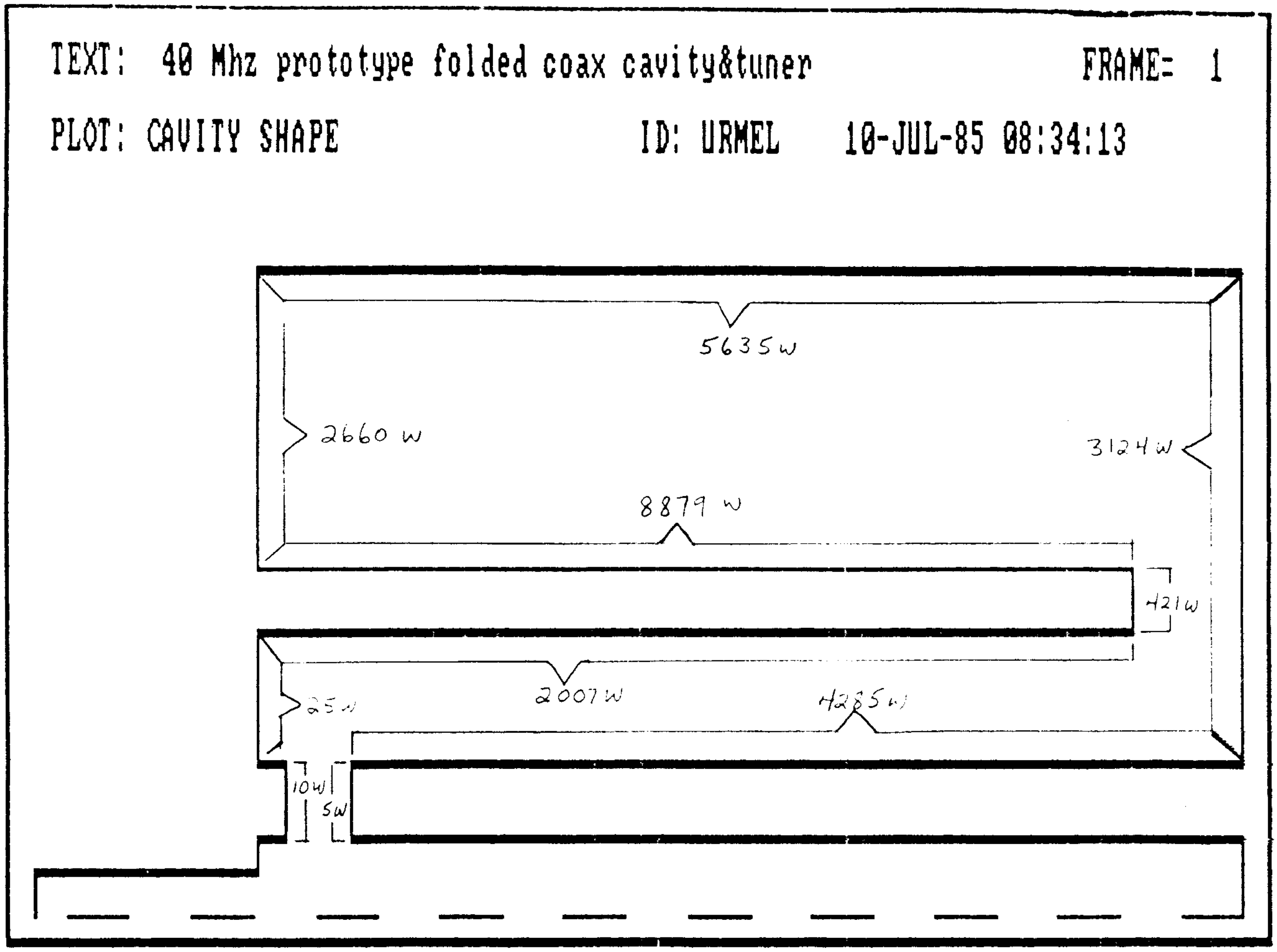

Figure 3. Power distribution in the folded-coaxial line with an effective gap voltage of 200 kV.

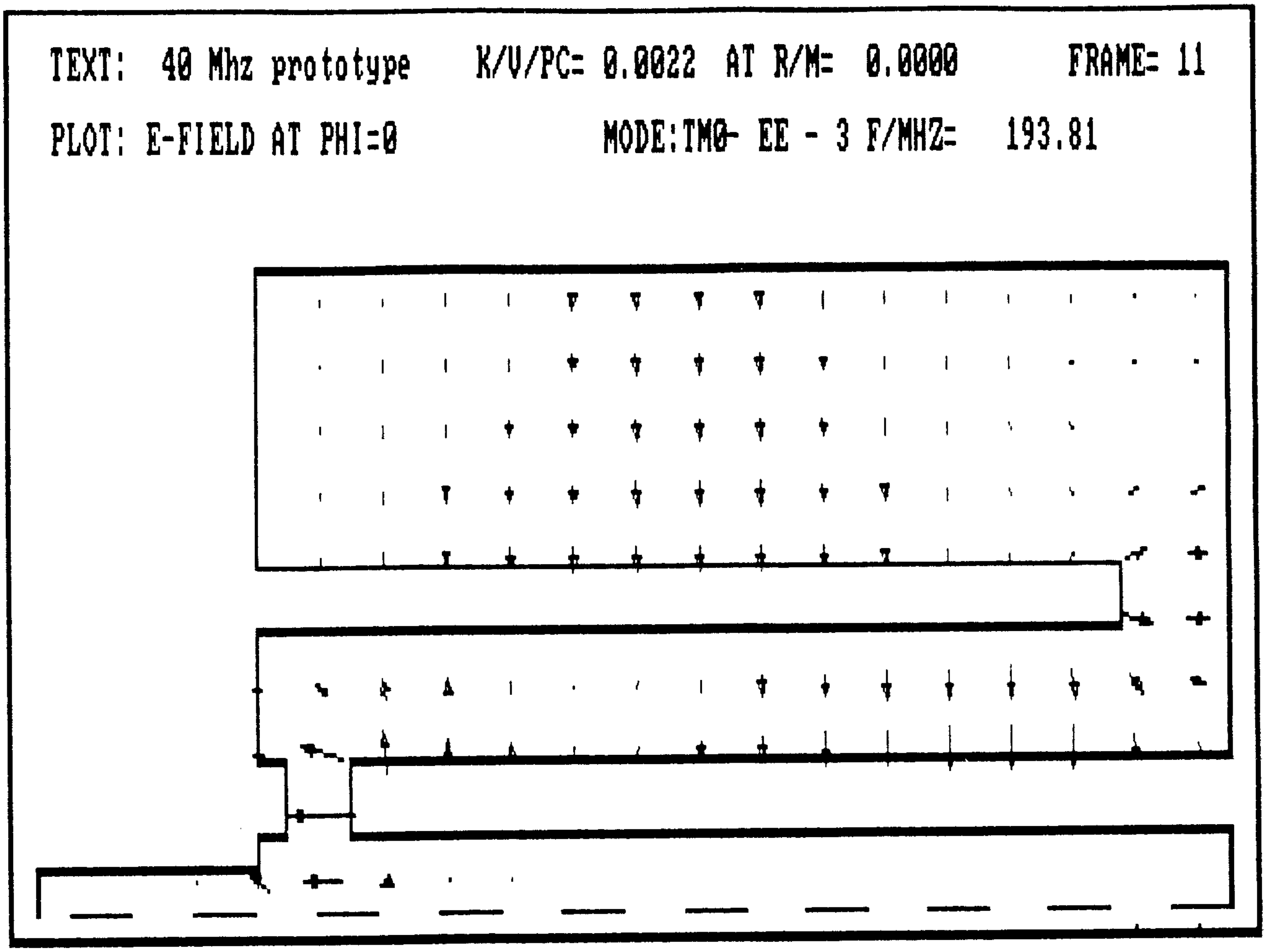

Figure 4. E-field pattern for a typical higher-order transverse mode.