Chapter 6 Home Work

1. Prove the phase velocity Vp and group velocity Vg for uniform waveguide meet the following relation $Vp*Vg = c^2$ (c is the speed of light).

2. There are beam pipes connecting to the end cavities of accelerator section in order to cut-off the RF wave and allow beam traversing through. Calculate the maximum diameter of the beam pipes for X-Band 11.424 GHz accelerator.

3. In Figure 6.6 there are four figures showing the electric field configuration for 0-mode, $\pi/2$-mode, $2\pi/3$-mode and π-mode disk-loaded structure. Plot the traveling wave axial electric field amplitude like the left lower plot for $\pi/2$-mode.

4. The electrons with 80 KeV kinetic energy enter a phase velocity Vp=c S-Band 2856 MHz TW accelerator structure, if the bunch length is 30^{O} with an initial center RF phase θ=0, calculate the optimized accelerator gradient for best bunching and final bunch length.

5. At very high gradient operation condition of accelerator structures, dark current can be created due to capturing and continuous acceleration of field-emitted electrons from high surface region of accelerator. If we assume the initial field-emitted electrons have ~ 0 kinetic energy, estimate that what is the threshold gradient for dark current capturing in X-Band (11.424 GHz), C-Band (5.712 GHz) and S-Band (2.856 GHz) accelerators.

6. Attached is a Table containing the specifications of several accelerator structures for high gradient studies at SLAC. T53VG3R is a constant surface field structure, but it is very close to a constant gradient structure. Based on the shunt impedance (approximately using average value) and total attenuation τ, please calculate the followings:

a) The input power needed for average gradient of 50MV/m in unloaded case (no beam).
b) For above unloaded case, the power dissipated in structure itself and the power left over in the end of this accelerator, (this power would be absorbed by outer matched loads).
c) The steady energy gain for an 1 Ampere beam.

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Structures Name	DS2S	T20VG5N	T105VG5N	T53VG5R	T53VG3R	SW20PIR	SW20PIL
Structure Type	Detuned	Constant Es	Constant Es	Constant Es	Constant Es	Constant Impedance	Constant Impedance
Length (cm)	46	20	105	53	53	20	20
Number of Cells	52	23	120	61	61	15	15
Cell Shape	DLWG	DLWG	DLWG	DLWG	DLWG	DLWG	DLWG
Phase Advance Per Cell	$2\pi/3$	$2\pi/3$	$2\pi/3$	$2\pi/3$	$2\pi/3$	π	π
HOM Manifold	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iris Dia. 2a (mm)	8.9 – 7.9	8.9 - 8.5	8.9 - 6.3	8.9 -7.8	7.8 - 6.3	9.5	9.5
Cell Dia. 2b (mm)	21.8 - 21.4	21.8 - 21.6	21.8 – 20.8	21.8 – 21.3	21.3 – 20.8	21.64	21.64
$\langle a \rangle / \lambda$	0.160	0.166	0.145	0.159	0.134	0.181	0.181
Disk Thickness, t (mm)	1.66 – 2.0	1.66	1.66	1.66	1.66	2.3	2.3
Filling time, T_f (ns)	35.0	14.2	116.6	42.3	74.3	123	123
Shunt Impedance, r (MΩ/m)	88.0	82 -86	82 - 107	82 - 92	92 -107	68.3	68.3
Group Velocity, v_g / c	5.0 – 3.0	5.0 – 4.4	5.0 – 1.6	5.0 – 3.3	3.3 – 1.6	N/A	N/A
<Q>, Fundamental Mode	~7000	~6857	~6820	~6843	~6797	~8860	~8860
Attenuation, τ	0.183	0.071	0.61	0.22	0.39	N/A	N/A
E_p / E_a	2.22-2.10	2.22 – 2.18	2.22 – 1.99	2.22 – 2.13	2.13 – 1.99	2.65	2.65
Coupler Design	Regular	Regular	Regular	Regular	Regular	Regular	Regular, 14% field reduction
Machining Method	Single Diamond	Single Diamond	Single Diamond	Regular	Regular	Regular	Regular
Cell Joint Method	Nested Brazing	Nested, Diffusion Bonding	Nested, Diffusion Bonding	Nested, Diffusion Bonding	Nested, Diffusion Bonding	Nested, Diffusion Bonding	Nested, Diffusion Bonding
Coupler Assembly	Brazing	Brazing	Brazing	Brazing	Brazing	Brazing	Brazing
Pre-Processing	C10-60s for front end parts	C10-5s W&D H2 firing	C10-5s W&D H2 firing	C10 - 60s W&D H2 firing	C10 - 60s W&D H2 firing	C10 - 60s W&D H2 firing	C10 - 60s W&D H2 firing
Completion Time	8/2000	12/2000	12/2000	3/2001	3/2001	4/2001	9/2001
Testing Time	11/00 – 2/01	3 – 4/01	3 – 4/01	8 – 9/01	8 – 9/01	8 – 9/01	11-12/01
Power Needed for $\langle E_a \rangle$=50 MV/m	39.0	43.4	40.0	42.1	24.5	7.2 ß=1	7.2 ß=1
Operated E-field $\langle E_a \rangle_{max}$ (MV/m)	73	73	73	81	86	70	70