SLAC-WP-084

Waveguide Coupler for X-band Defectors

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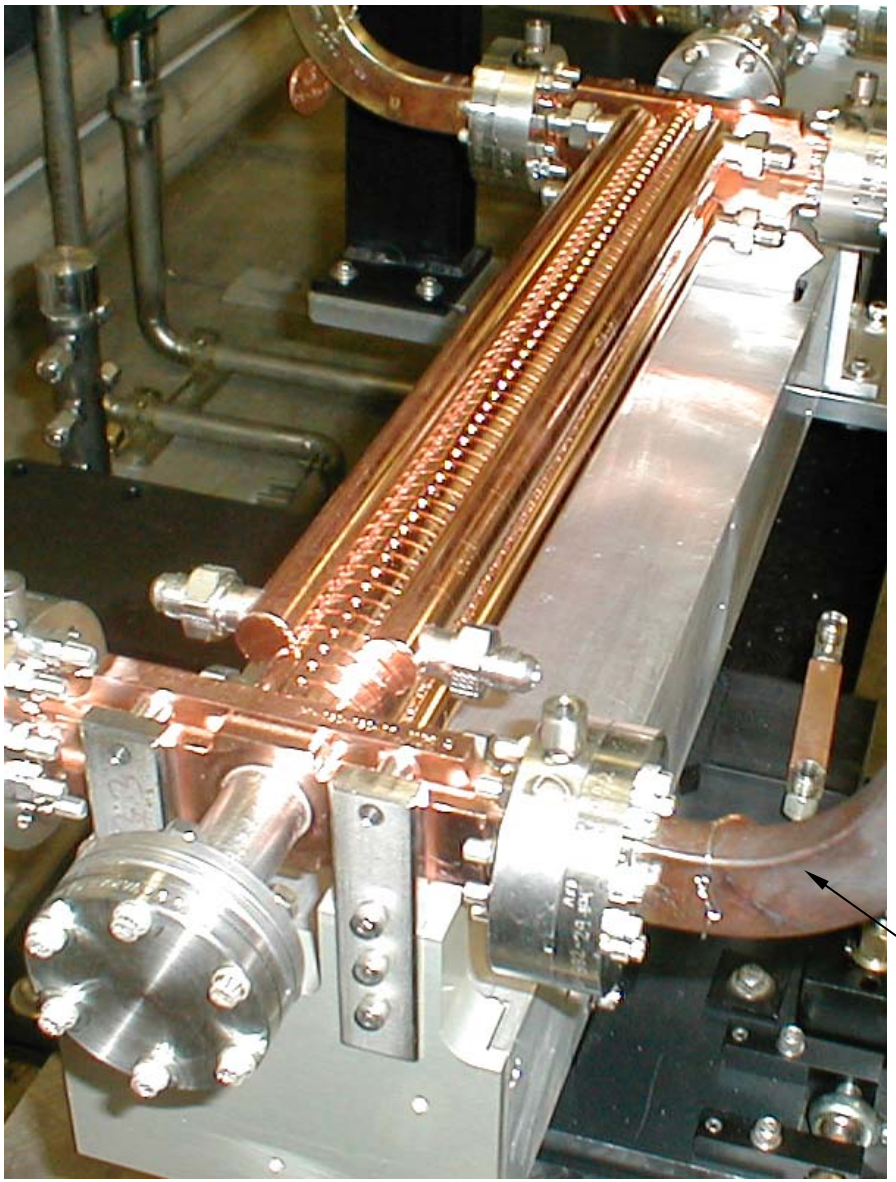
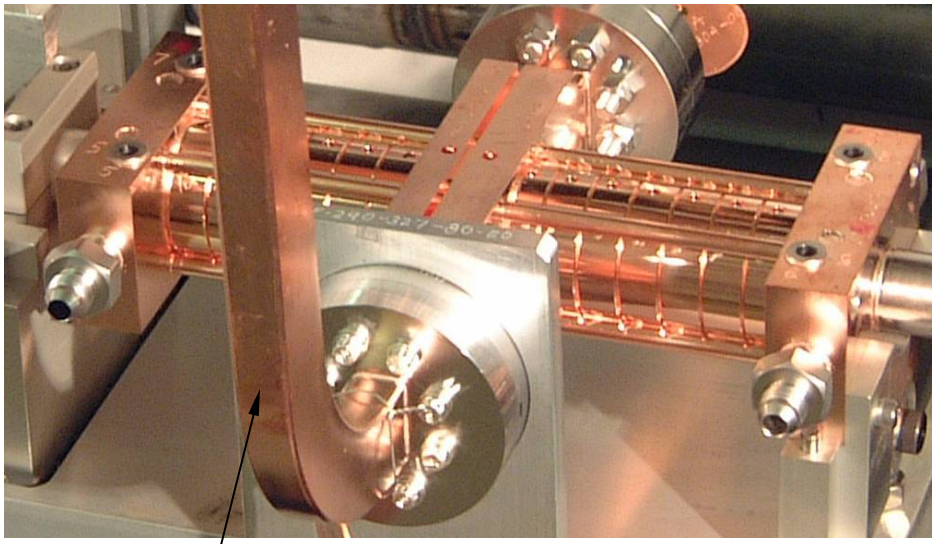
Outline

- **Waveguide Coupler**
- **Traveling Wave Deflector**
- **Standing Wave Deflector**

X-band, 11.4GHz accelerating structures



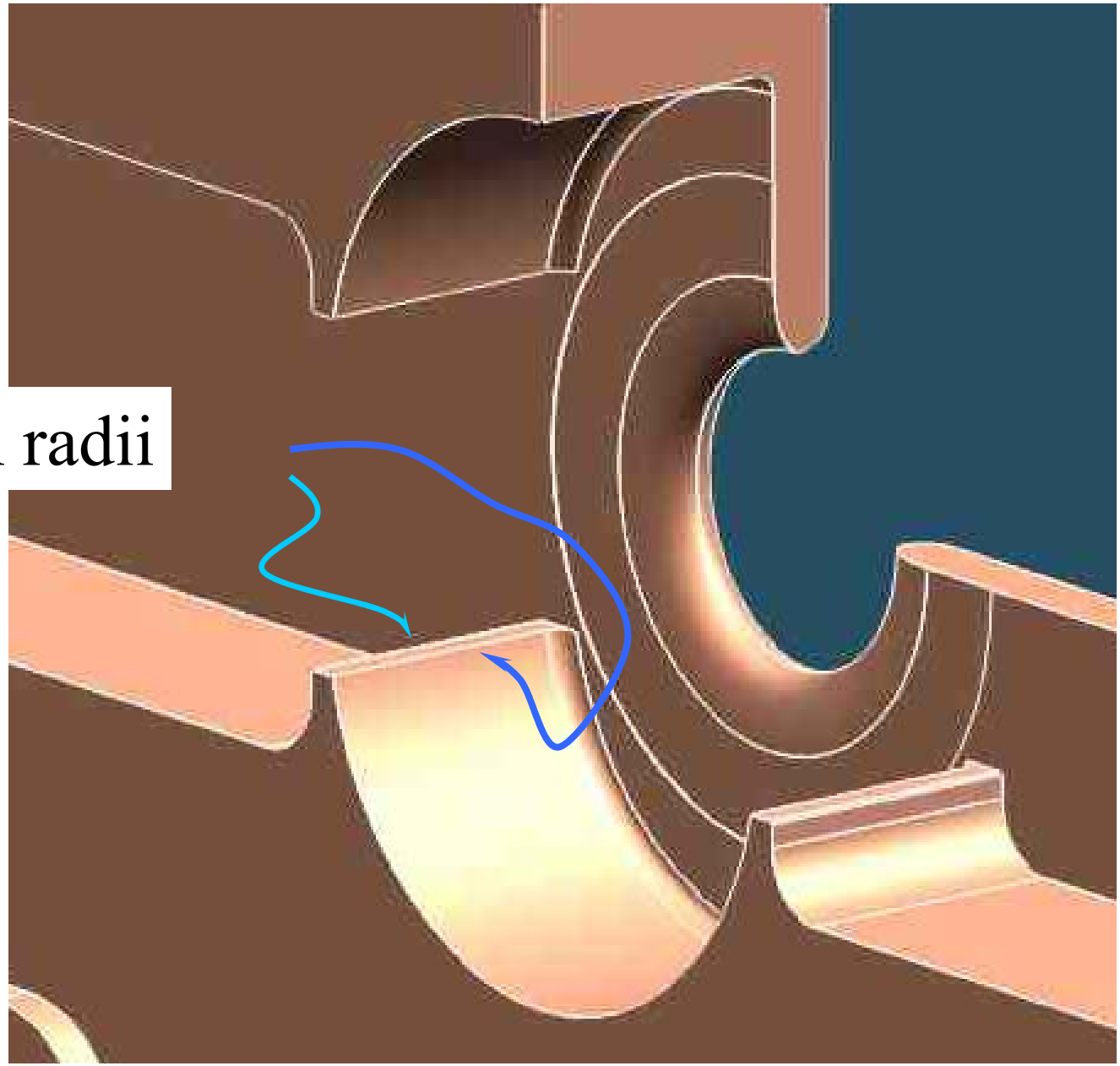
Traveling Wave, length ~60 cm



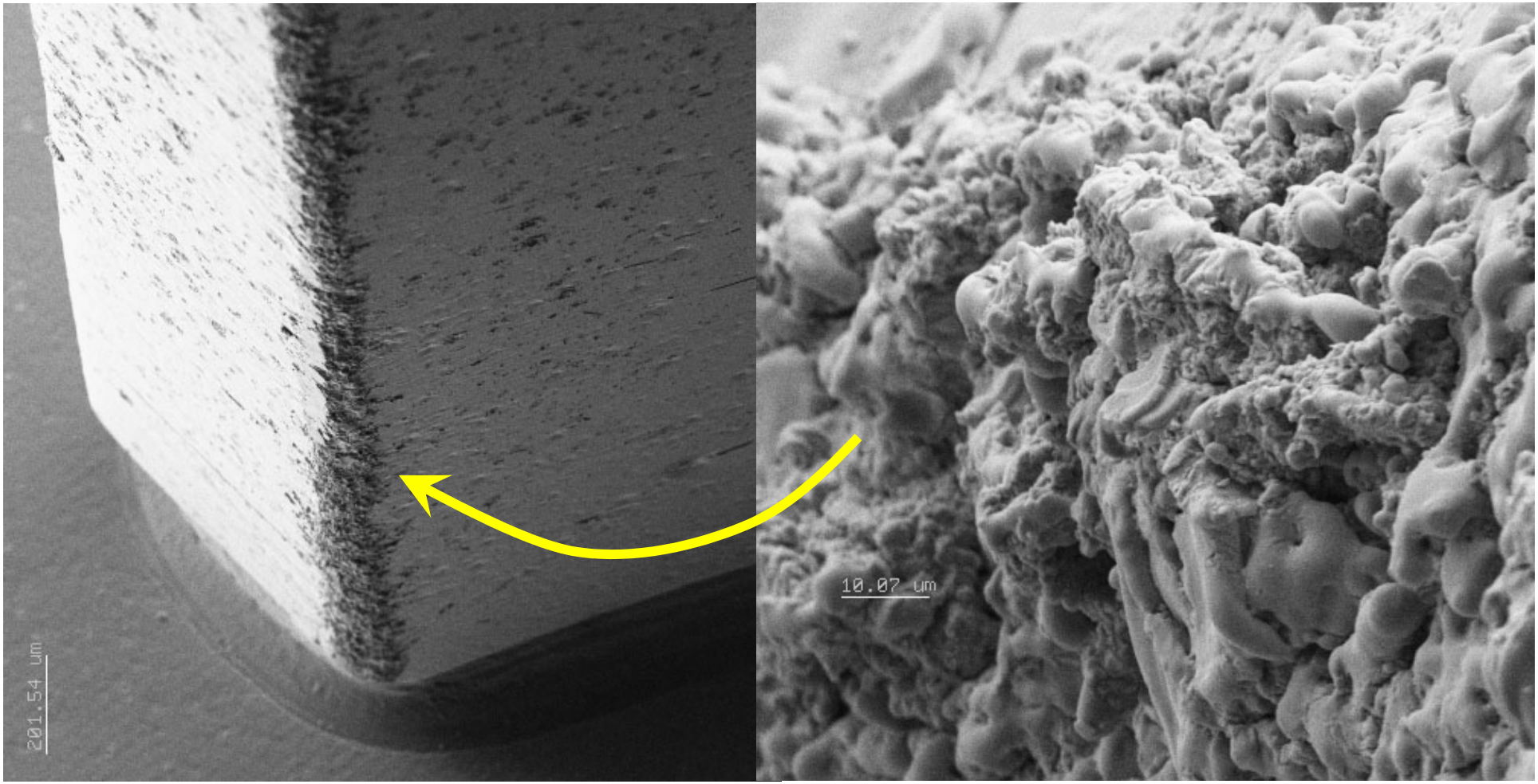
Standing Wave, length ~20 cm

WR90

“Standard” Coupler geometry

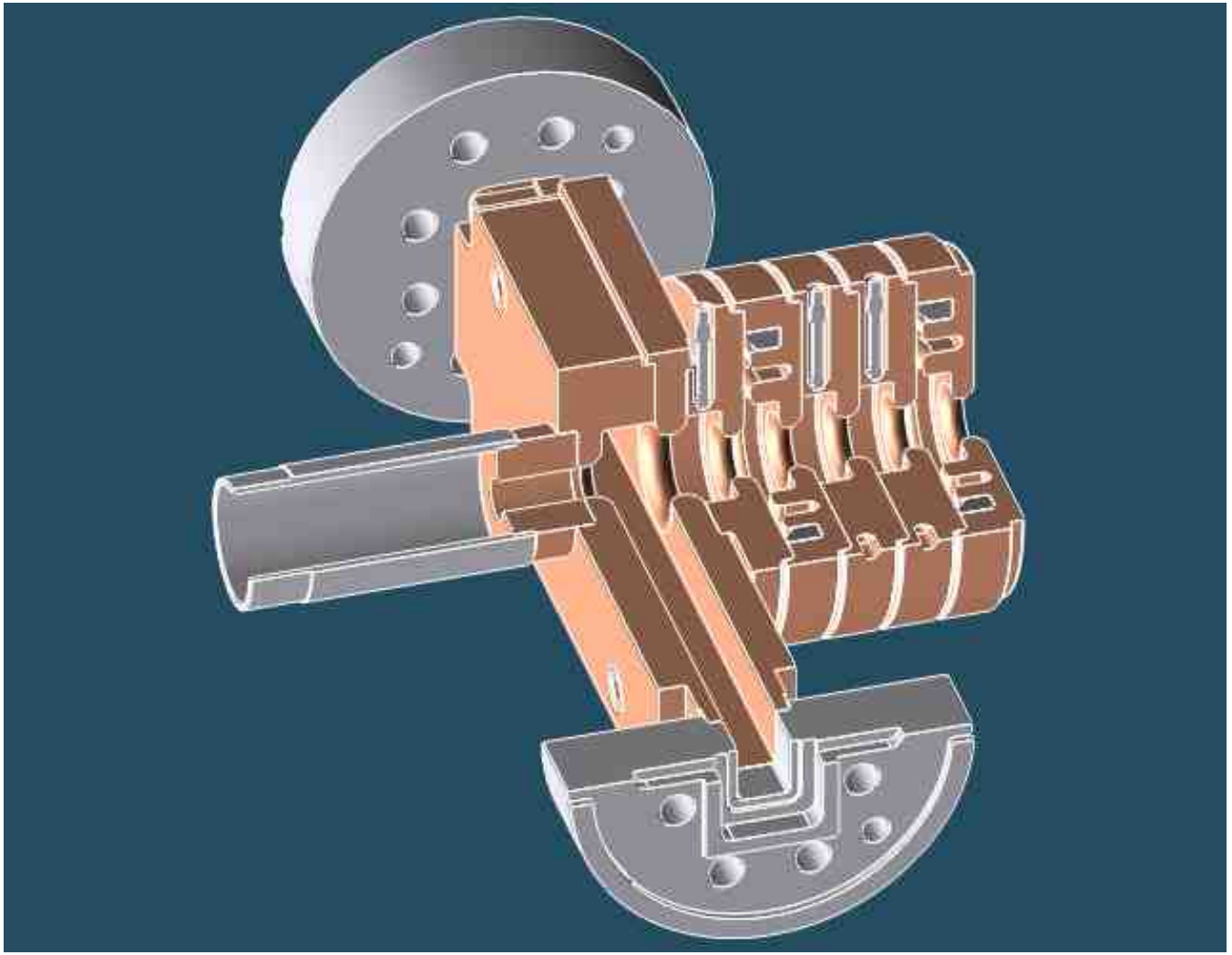


Typical edge damage on the cell side of the Horns



R. Kirby ***et al.***

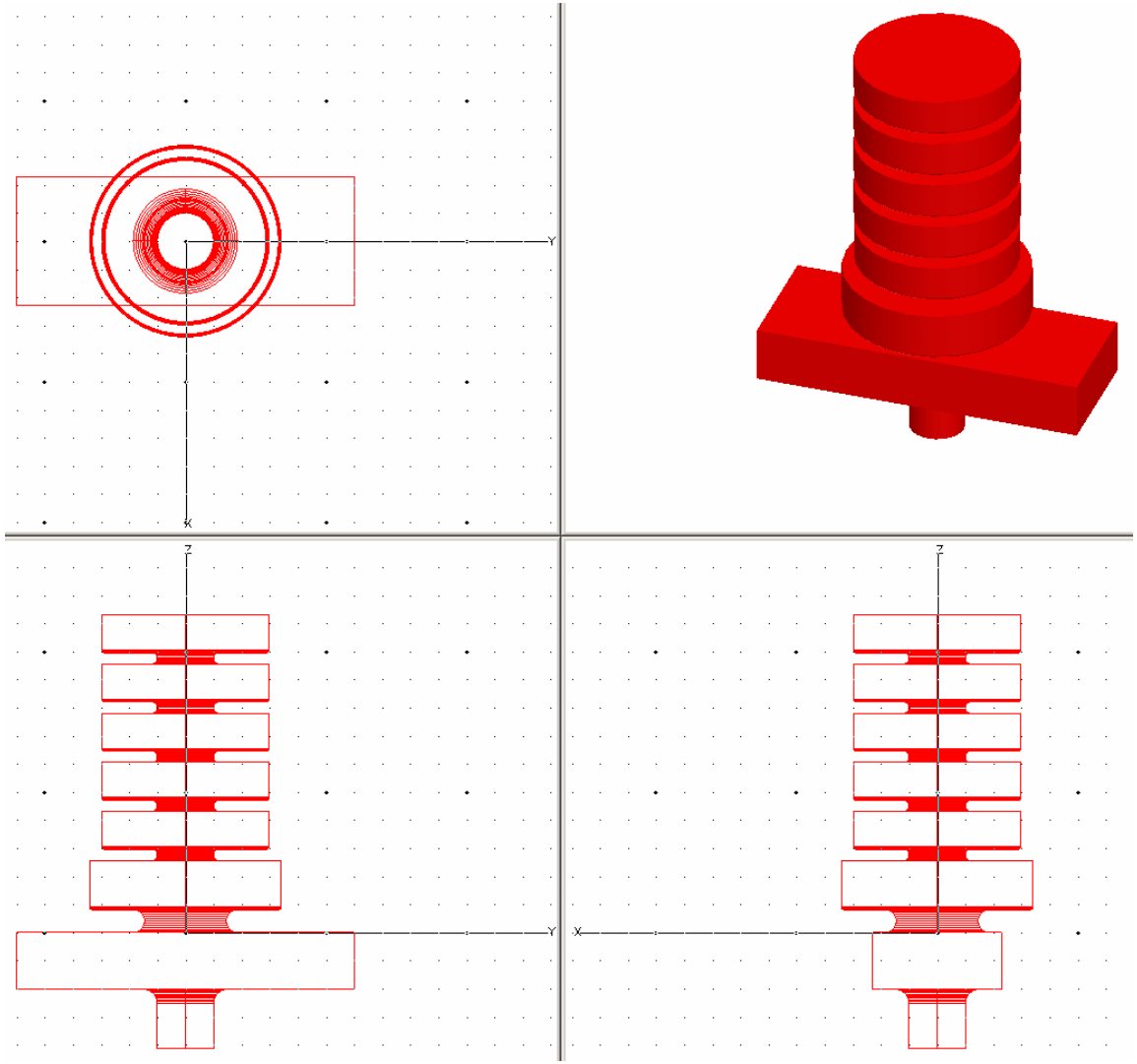
Waveguide coupler



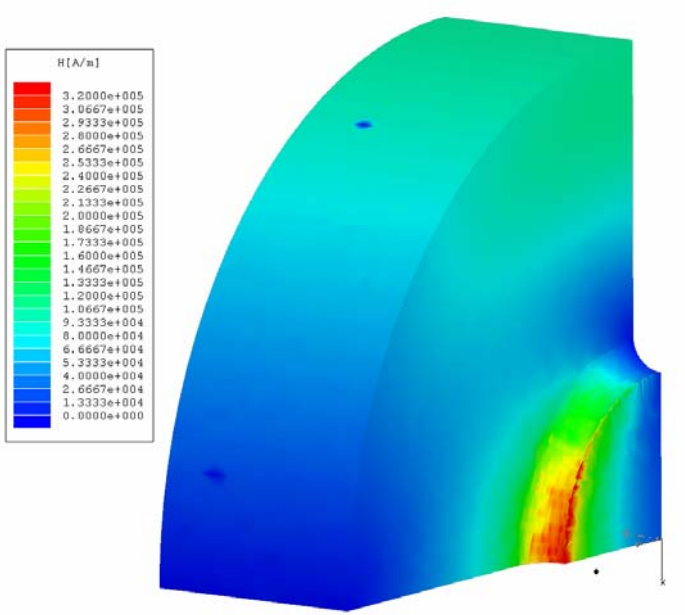
Christopher Nantista, Sami Tantawi, and Valery Dolgashev,
Low-field accelerator structure couplers and design techniques,
Phys. Rev. ST Accel. Beams 7, 072001 (2004) [7 pages]

11.4 GHz Traveling Wave Deflector for ~10 fs diagnostics of GeV beams

Waveguide coupler for TW X-band deflector

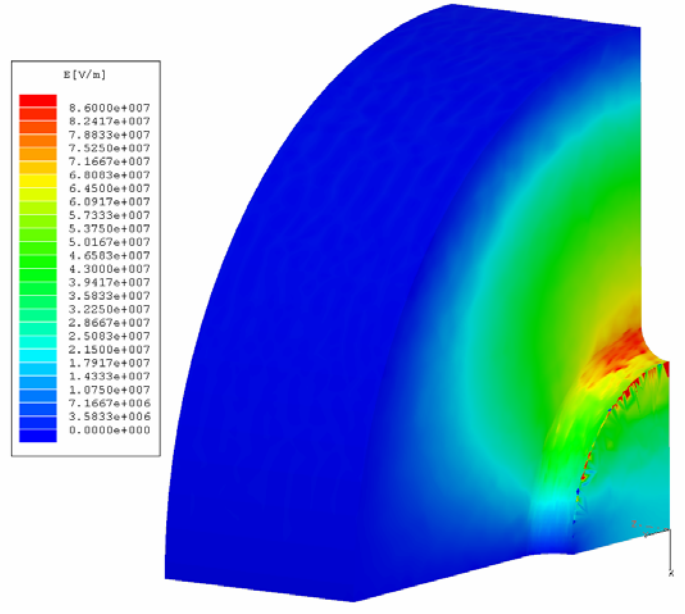


Periodic 2Pi/3 traveling wave deflector, 20 MW, deflecting gradient 31 MV/m



Maximum surface magnetic fields 320 kA/m,
Pulse heating 14 deg. C for 100 ns pulse.

a = 5 mm
t = 2 mm, round iris
Q=6,252



Maximum surface electric fields 86 MV/m.

$$\text{Length} := 0.5\text{m} \qquad \text{Pmy} := 20\text{MW}$$

$$\frac{\text{Length}}{\text{vg}\cdot c} = 51.80278916978\text{ns}$$

$$\text{Zeff}\cdot\frac{1-e^{-\alpha\cdot\text{Length}}}{\alpha}\cdot\sqrt{\text{Pmy}} = 13.3210^{6}\text{V}$$

$$\text{Qunl} = 6252$$

$$\text{Zeff}\cdot\sqrt{\text{Pmy}} = 30.781753434\,7\frac{\text{V}\cdot 10^{6}}{\text{m}}$$

$$\text{vg} = 3.2196\%$$

$$e^{-\alpha\cdot\text{Length}} = 0.7429745571$$

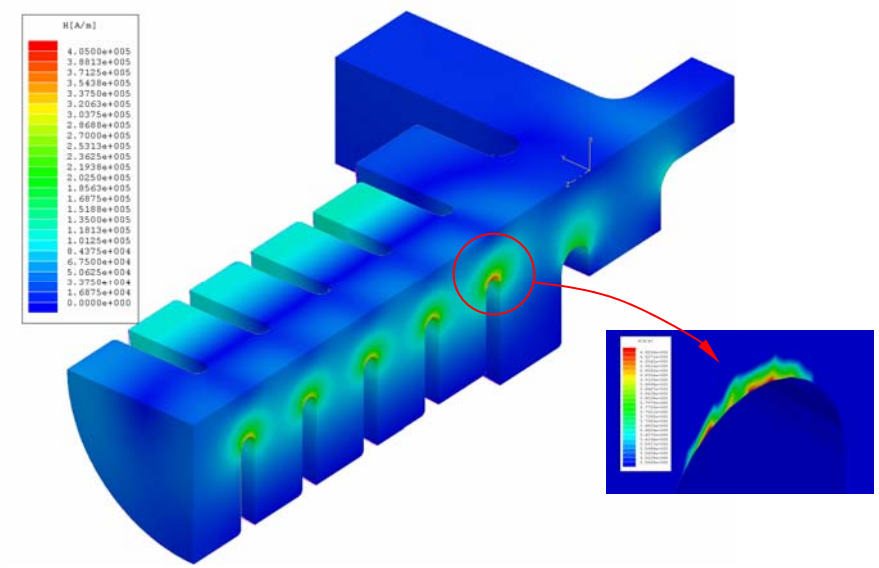
$$\alpha = 0.594186956\,7\frac{1}{\text{m}}$$

$$\text{Zeff} = 6.883009314\,7\frac{1}{\text{m}}\frac{10^{6}\text{V}}{\sqrt{\text{MW}}}$$

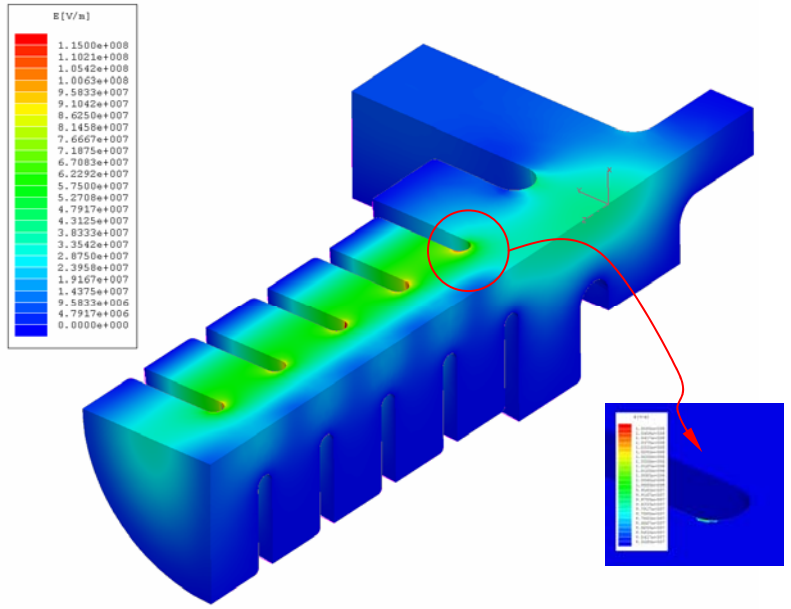
$$\text{P} = 0.222355\text{W}\,10^{6}$$

$$\text{Zeff} = 68.830093146\,6\frac{\text{kV}}{\sqrt{\text{MW}}}\cdot\frac{1}{\text{cm}}$$

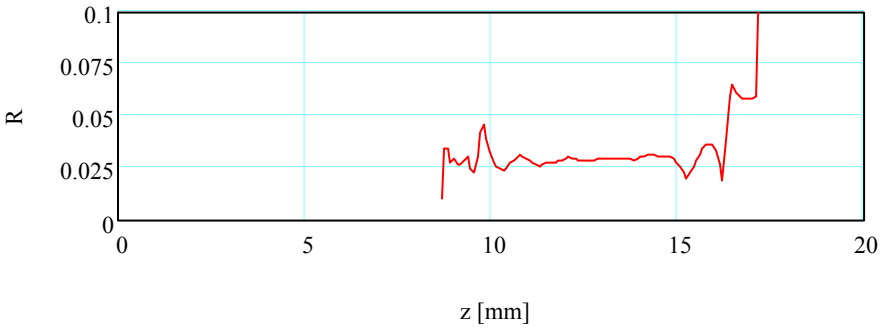
Waveguide coupler for TW X-band deflector, 20 MW of transmitted power, or 21.3 MeV kick for 89 cm structure



Maximum surface magnetic fields ~400 kA/m,
Pulse heating 22 deg. C for 100 ns pulse.



Maximum surface electric fields ~100 MV/m.



Parameters of TW X-band deflector

Frequency	11.424 GHz
Beam pipe diameter	10 mm
One cell length	8.747 mm
Phase advance per cell	$2\pi/3$
Kick per meter [MeV/Sqrt [MW]]	31 MeV/m/Sqrt(20 MW)
102 cell structure kick	21.3 MeV/Sqrt(20 MV)
Cell Q	6252
Attenuation	0.59 [1/m]
Maximum Electric field	100 MV/m / Sqrt(20 MW)
Maximum Magnetic field	400 (kA/m) / Sqrt(20 MW)
Group velocity/ speed of light	3.2 %
Filling time	92 ns
Structure length (with beam pipes)	~94 cm

An X-Band Transverse RF Deflector for the LCLS

P. Emma

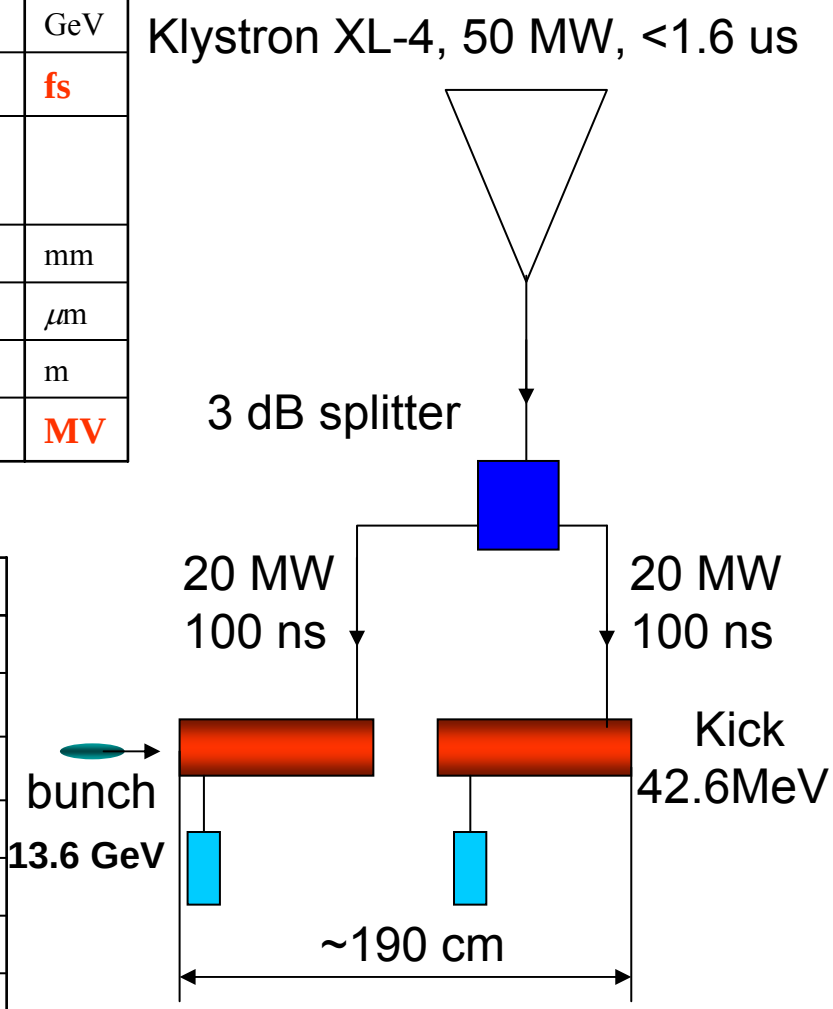
Oct. 18, 2006

Table 1. Parameters for a 10-fs temporal resolution using an X-band RF deflecting cavity.

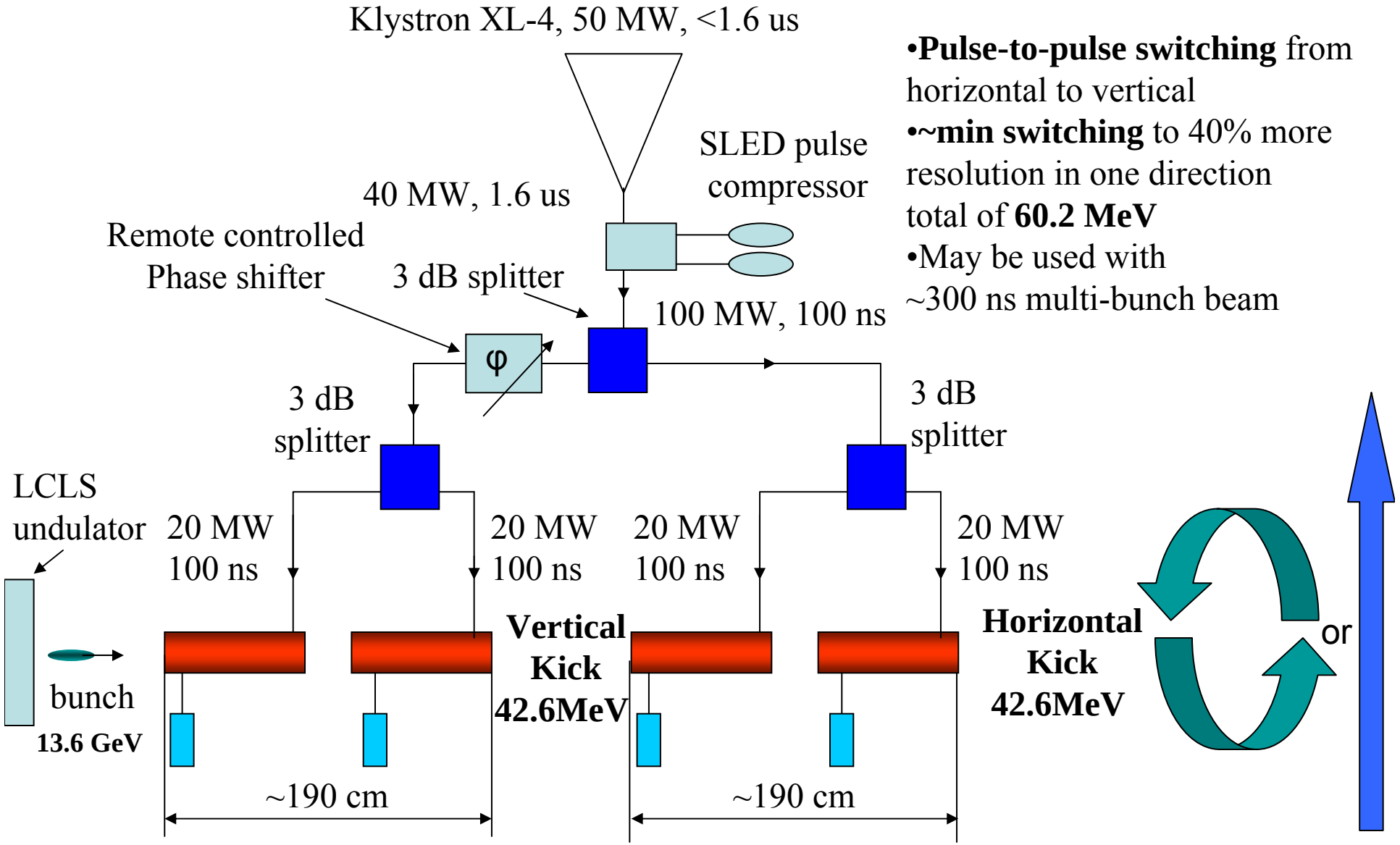
Parameter	**symbol**	**value**	**unit**
Electron energy	E	13.6	GeV
Desired temporal resolution	Δt	**10**	**fs**
Offset of Δt-particle on screen, in units of rms beam size	n	2	
RF wavelength of deflector (X-band)	λ	26	mm
Vertical normalized rms emittance	ε_N	1	μm
Vertical beta function at the center of the RF deflector	β_d	50	m
Peak vertically accelerating voltage seen by beam	V	**33**	**MV**

Table 3. Approximate specifications for an X-band RF deflecting cavity.

Parameter	**symbol**	**value**	**unit**
Maximum repetition rate	f	120	Hz
Minimum iris radius (if located after undulator)	r	**5**	**mm**
Maximum cavity length (approx.)	L	**2**	**m**
Minimum RF pulse length	$\Delta\tau_{RF}$	100	ns
RF frequency	f_{RF}	11.424	GHz
RF phase stability at $f > 1$ Hz (rms)	φ_{rms}	0.05	deg-X
RF relative amplitude stability (rms)	$\Delta V/V_0$	1	%



"After undulator" circularly polarized bunch analyzer with <10 fs horizontal and vertical resolution



- **Pulse-to-pulse switching** from horizontal to vertical
- **~min switching** to 40% more resolution in one direction total of **60.2 MeV**
- May be used with ~300 ns multi-bunch beam

LOLA IV *vs.* X-band TW deflector

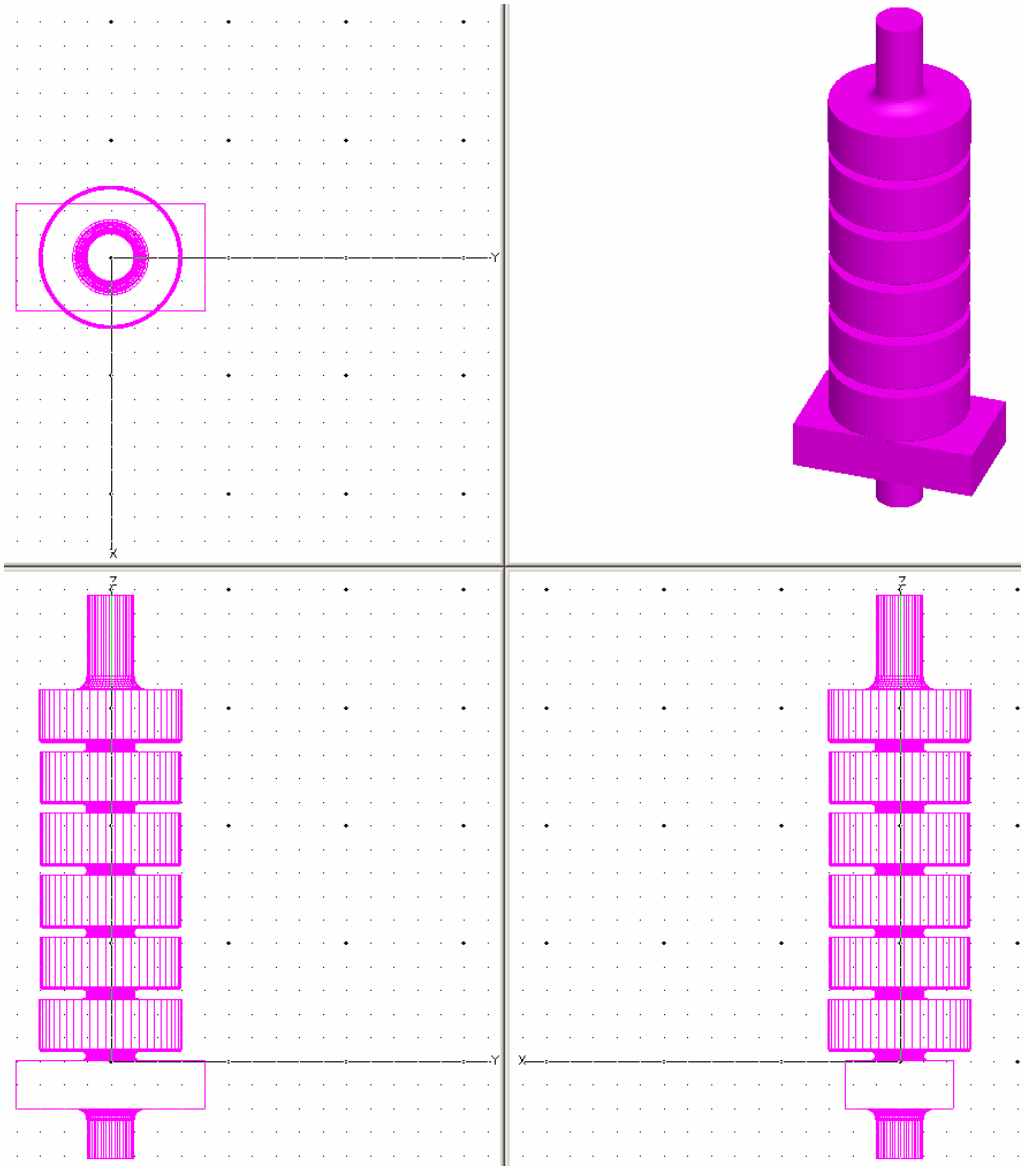
	LOLA IV	X-band TW deflector
Frequency	2.856 GHz	11.424 GHz
Length	244 cm	94 cm
Power	20 MW	20 MW
Kick	19 MV	85 MV /(11.424/2.586)

G. A. Loew, O. H. Altenmueller, *Design and Applications of R.F. Deflecting Structures at SLAC*, PUB-135, Aug. 1965.

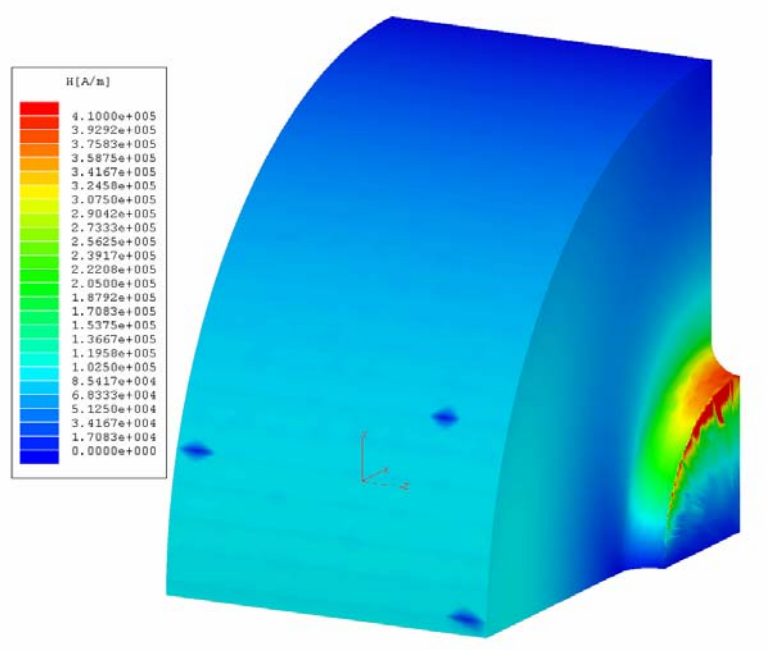
Paul Emma *et al*., *A Transverse RF Deflecting Structure for Bunch Length and Phase Space Diagnostics*, LCLS-TN-00-12, August 29, 2000

Standing Wave Deflector for ~10 fs diagnostics of MeV beams

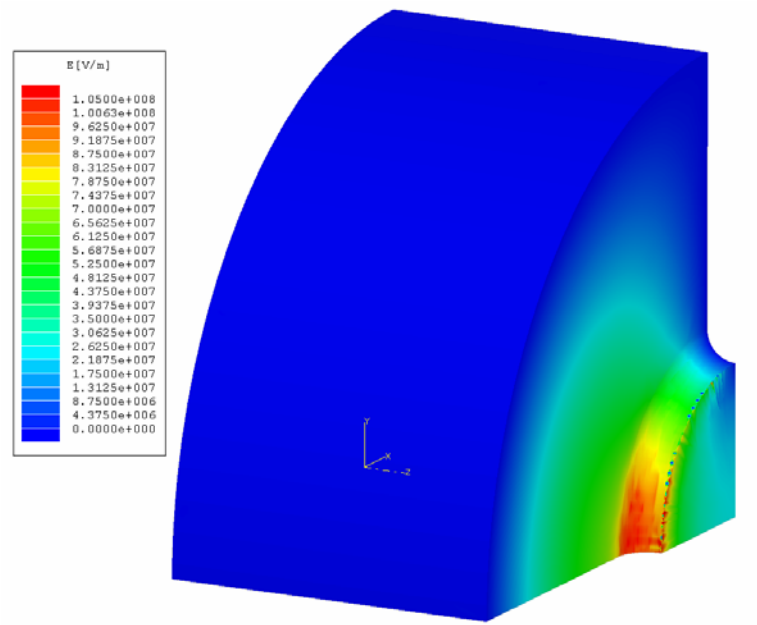
Waveguide coupler for 6 cell SW 11.424 GHz deflector



Periodic cell of Pi standing wave deflector, 0.25 MW/cell, deflecting gradient 26 MV/m



Maximum surface magnetic fields 410 kA/m,
Pulse heating 23 deg. C for 100 ns pulse.

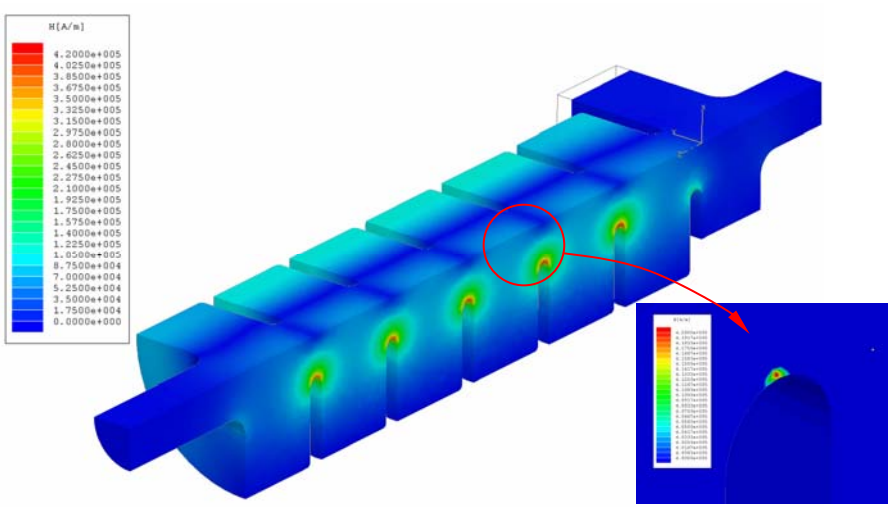


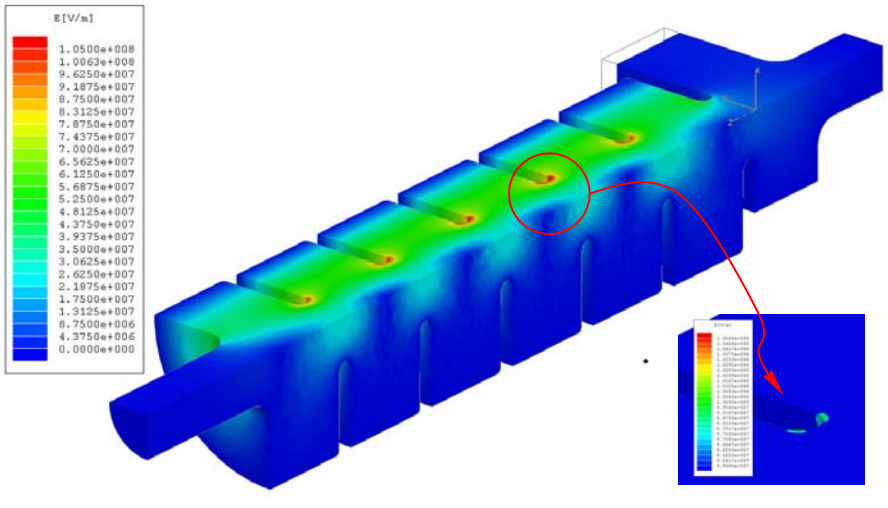
Maximum surface electric fields 105 MV/m.

a = 6 mm
t = 2 mm, round iris
Q=7,792

	Frequency (GHz)	Q
Mode 1	(1.14266e+001, 7.33191e-004)	7.79237e+003

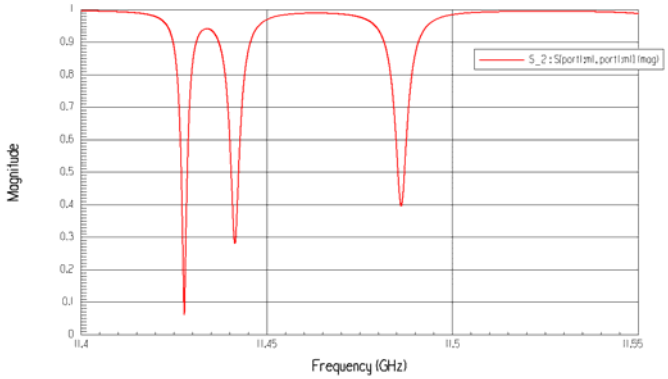
Waveguide coupler for 6 cell SW X-band deflector, 1.5 MW of input power, deflection 2 MeV





Maximum surface magnetic fields ~420 kA/m,
Pulse heating 24 deg. C for 100 ns pulse.

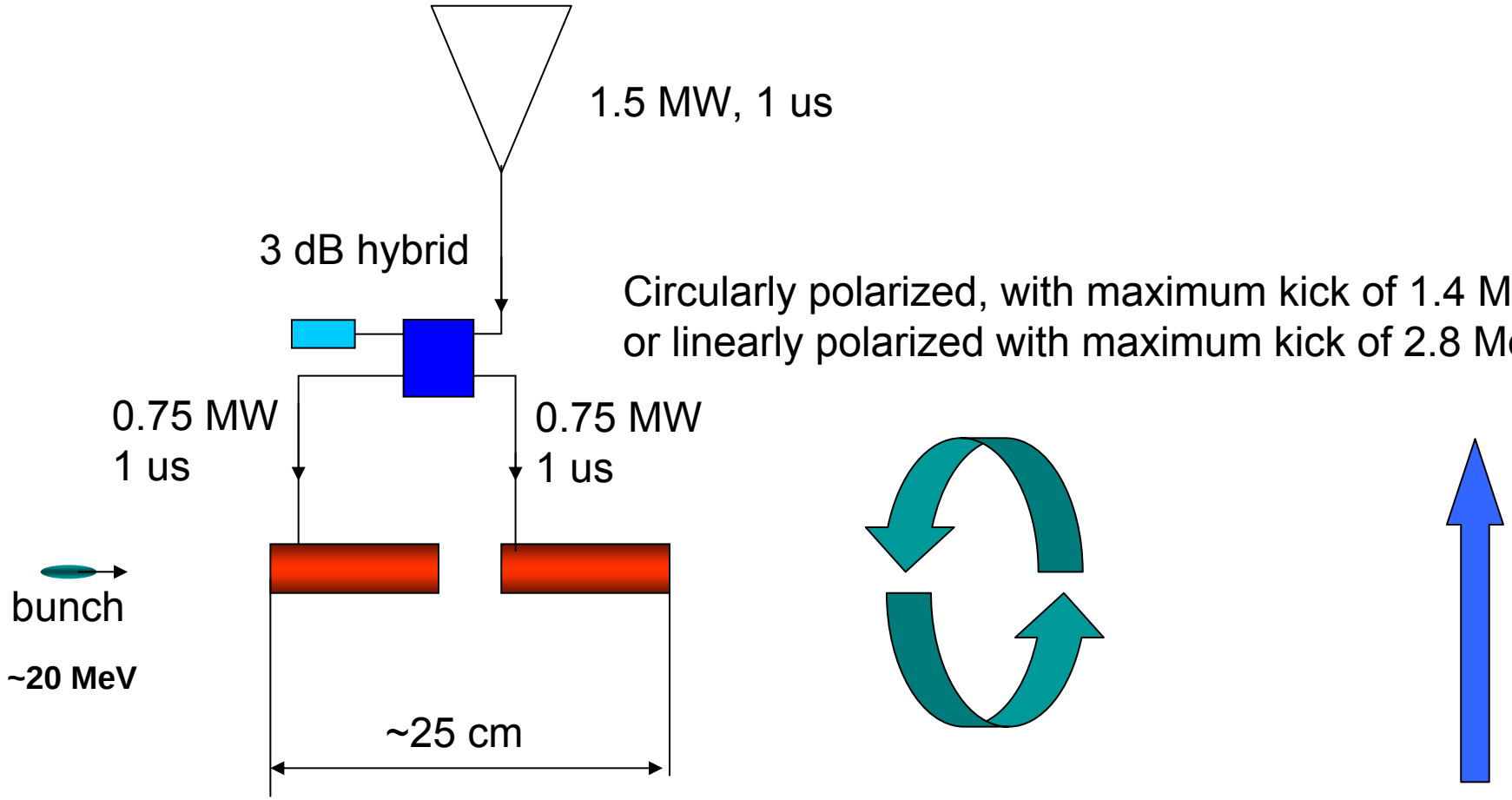
Maximum surface electric fields ~105 MV/m.



Parameters of 6 cell X-band SW deflector

Frequency	11.424 GHz
Beam pipe diameter	10 mm
One cell length	13.121 mm
Phase advance per cell	π
One cell kick	0.34 MeV/Sqrt(0.25 MW)
Structure kick (6 cells)	2 MeV/Sqrt(1.5 MW)
Unloaded Q	7800
Loaded Q	3800
Maximum Electric field	105 MV/m / Sqrt(1.5 MW)
Maximum Magnetic field	420 (kA/m) / Sqrt(1.5 MW)
Structure length (with beam pipes)	12 cm
Near mode separation	13.6 MHz

Application of SW deflector



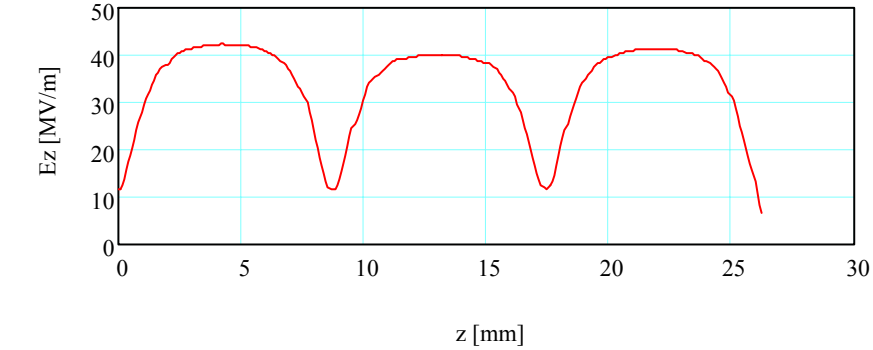
J. Haimson *et al.*, A *Circularly Polarized Beam Deflector for Direct Measurement of Ultra Short Electron Bunches*, Advanced Accelerator Concepts: Tenth Workshop, AIP, 2002, pp. 810-820

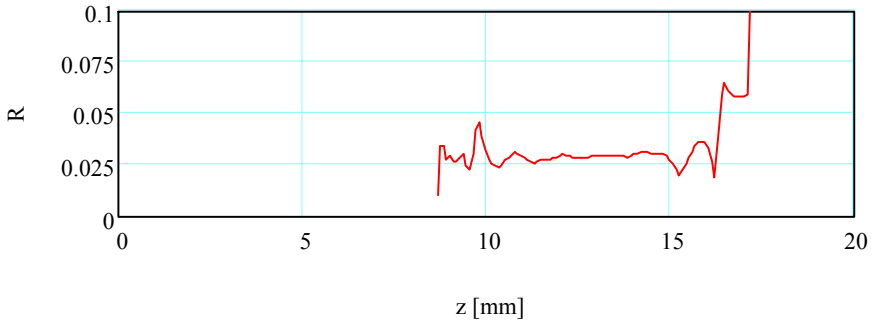
Summary

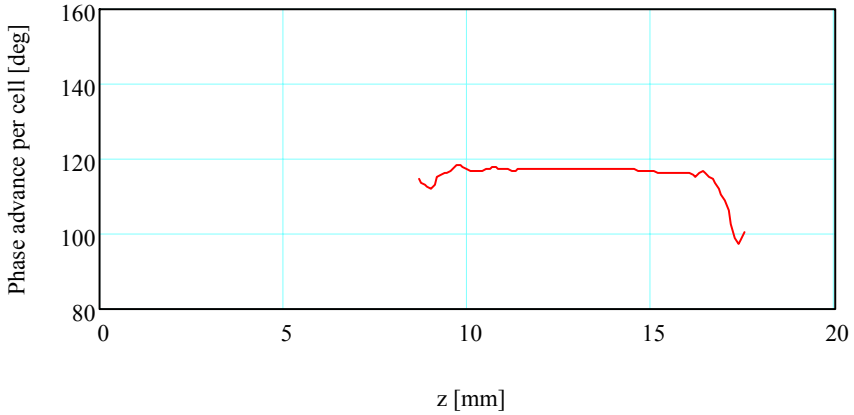
Technology developed for the NLC and for recent high gradient research may help building advanced ~fs beam diagnostics

More Slides

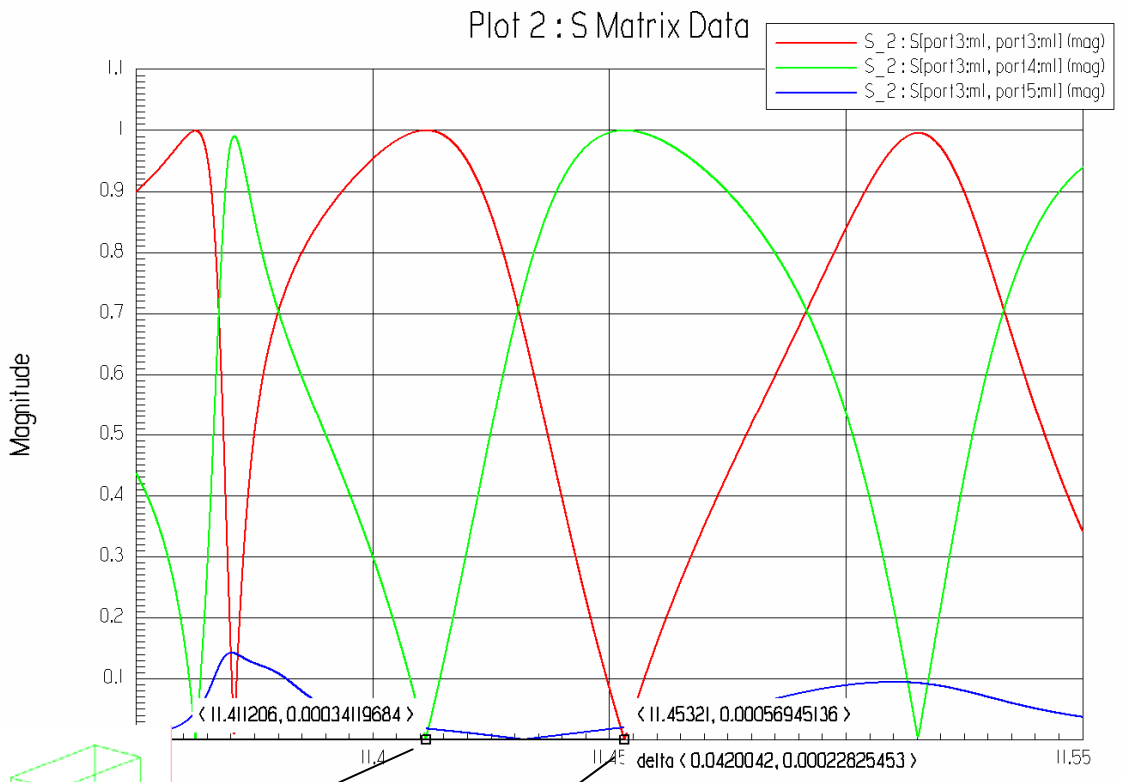
Calculation of refection using Ez 4 mm off axis, 20 MW transmitted power

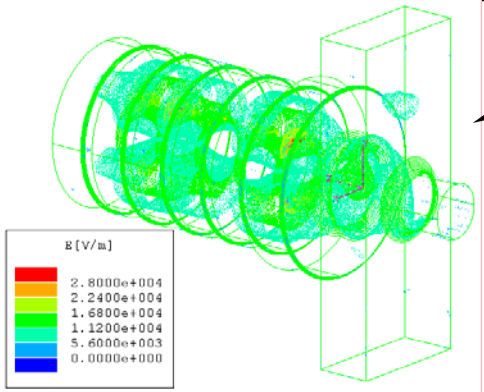


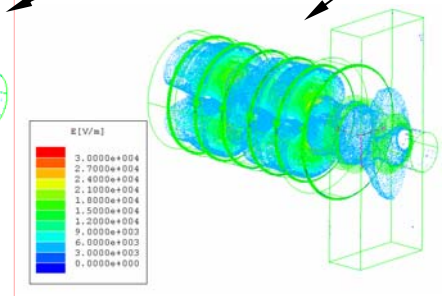




Looking for trapped modes (none found)



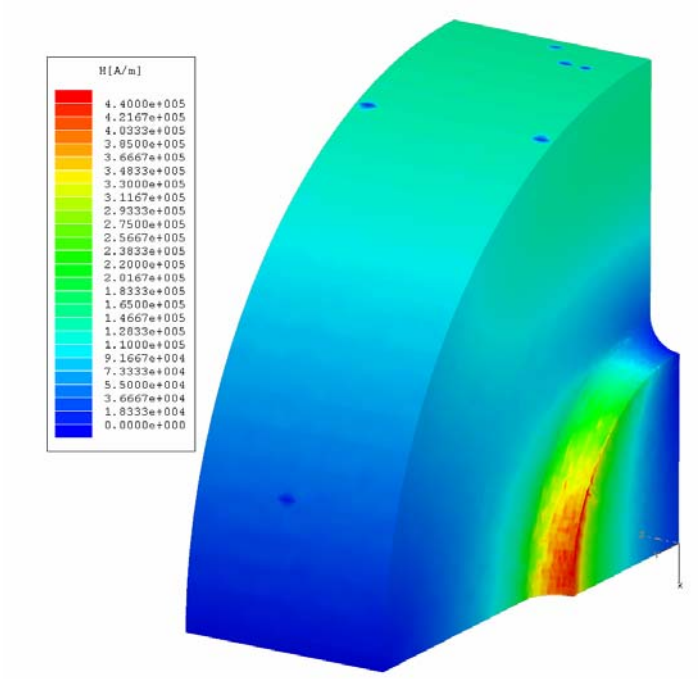




Scattering Matrix at 11.424 GHz for Adaptive Pass 9 (Phase in degrees)

	port3:m1	port4:m1	port5:m1
port3:m1	(0.88400, 47.253)	(0.46743, -42.759)	(0.00746, -94.279)
port4:m1	(0.46743, -42.759)	(0.88400, 47.236)	(0.00735, -94.740)
port5:m1	(0.00746, -94.279)	(0.00735, -94.740)	(0.99995, -28.391)

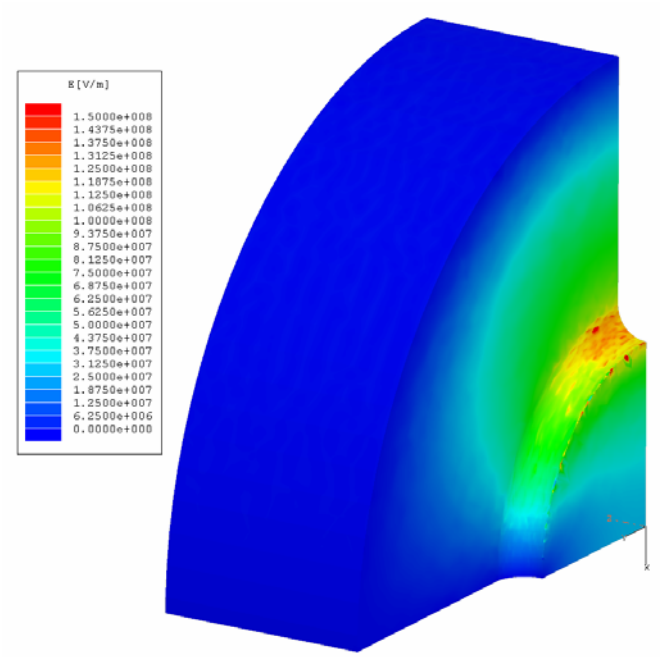
Periodic cell of 2Pi/3 traveling wave deflector, 20 MW, deflecting gradient 34 MV/m



Maximum surface magnetic fields 440 kA/m,
Pulse heating 26 deg. C for 100 ns pulse.

a = 6 mm
t = 2 mm, round iris
Q=6,252

	Frequency (GHz)	Q
Mode 1	(1.14204e+001, 9.38269e-004)	6.08591e+003



Maximum surface electric fields 150 MV/m.

$\text{Length} := 0.5\text{m} \qquad \text{Pmy} := 20\text{MW}$

$\text{Zeff} \cdot \frac{1 - e^{-\alpha \cdot \text{Length}}}{\alpha} \cdot \sqrt{\text{Pmy}} = 12.9110^{6}\text{V}$

$\text{Zeff} \cdot \sqrt{\text{Pmy}} = 33.7647969185 \frac{\text{V} \cdot 10^{6}}{\text{m}}$

$e^{-\alpha \cdot \text{Length}} = 0.5692883478$

$\text{Zeff} = 7.5500381156 \frac{1}{\text{m}} \frac{10^{6}\text{V}}{\sqrt{\text{MW}}}$

$\text{Zeff} = 75.5003811561 \frac{\text{kV}}{\sqrt{\text{MW}}} \cdot \frac{1}{\text{cm}}$

$\frac{\text{Length}}{\text{vg} \cdot c} = 95.5619207326\text{ns}$

$\text{Qunl} = 6085.91$

$\text{vg} = 1.7453\%$

$\alpha = 1.1267364215 \frac{1}{\text{m}}$

$P = 0.394241\text{W}\ 10^{6}$

$\text{freq} = 11.4204474572\text{GHz}$