Quarter Wave Transformer System Parameter Set

J. C. Sheppard, et al

SLAC

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Nominal Source Parameters

Parameter	Symbol	Value	Units
Bunch Population	N_b	2×10^{10}	#
Overhead Factor	F	1.5	#
Bunches per pulse	n_b	2625	#
Bunch spacing	t_b	369	ns
Pulse repetition rate	f_{rep}	5	Hz
Injection Energy (DR)	E_0	5	GeV
Beam Power (x1.5)	P_o	300	kW
Polarization e-(e+)	P	80(30)	%

Positron Source Layout

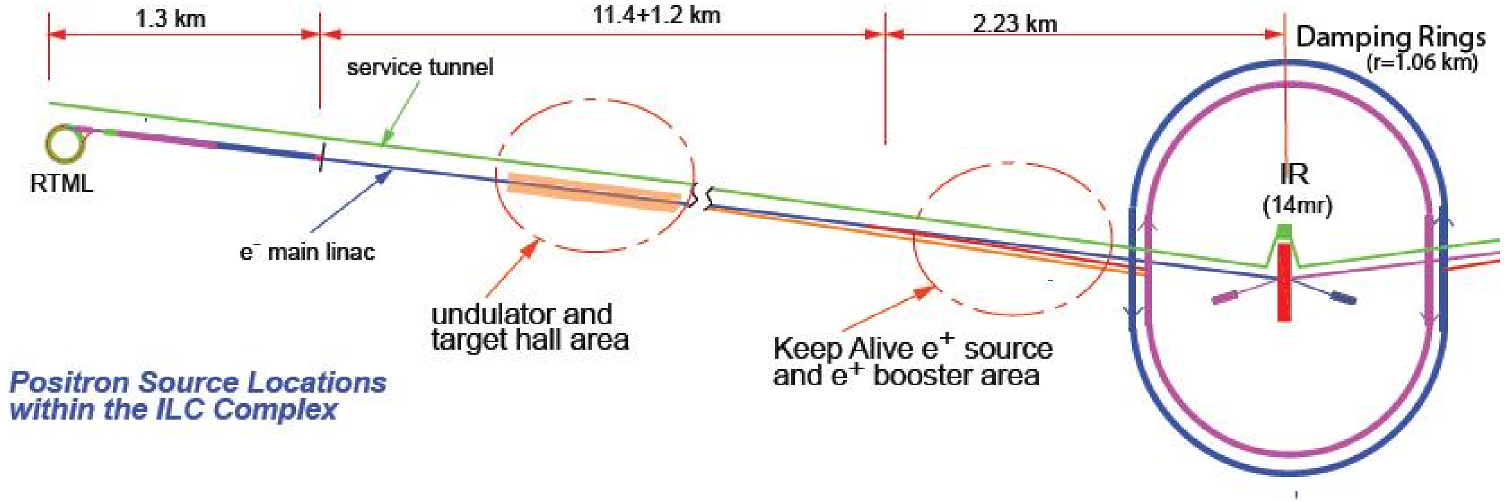


FIGURE 2.3-1. Layout of the Positron Source in the ILC

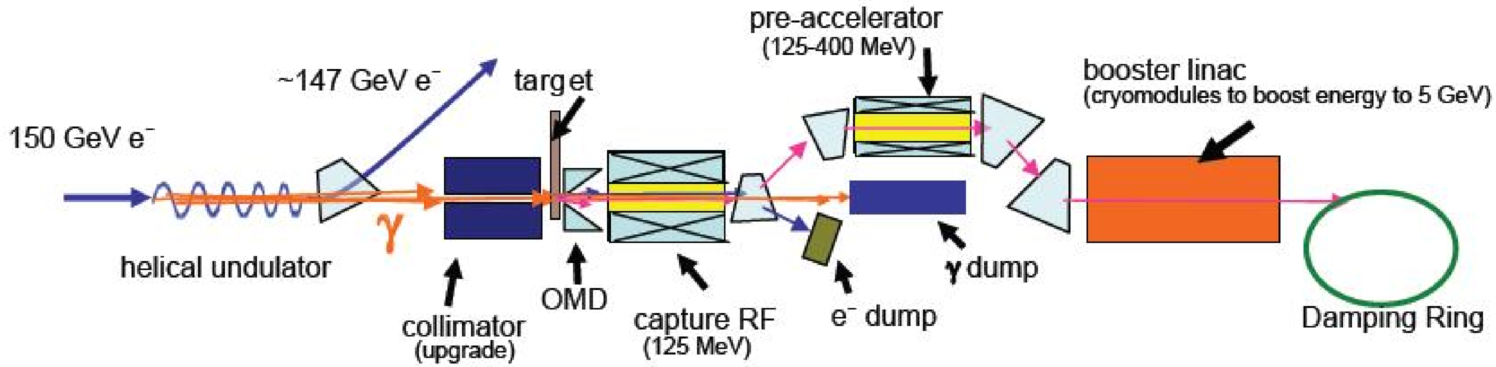


FIGURE 2.3-2. Overall Layout of the Positron Source

The Problem

The RDR assumes a Pulsed Flux Concentrator OMD

The undulator length and target parameters are specified by the simulated capture efficiency

Very little work has been done to assure the viability of a 1-ms, 7-T, 5 Hz flux concentrator

Proposal is to baseline the ILC Positron System that incorporates/substitutes for the OMD a discrete, dc solenoidal lens downstream of the target

Pulsed Flux Concentrator

Americas

Pulsed Flux Concentrator, circa 1965: Brechna et al.

1532 BRECHNA, HILL, AND BAILEY

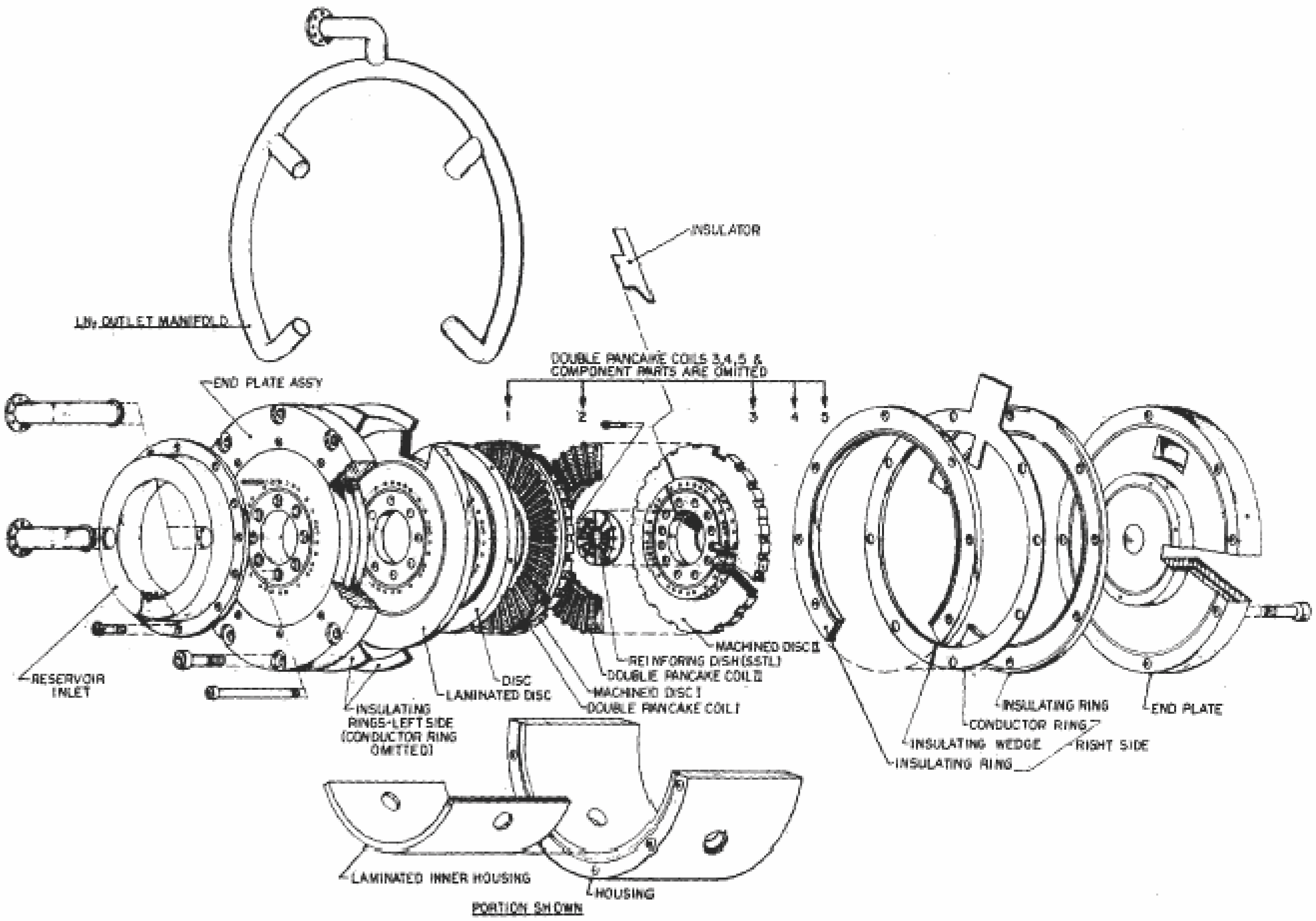


FIG. 5. Exploded view of flux-concentrator assembly.

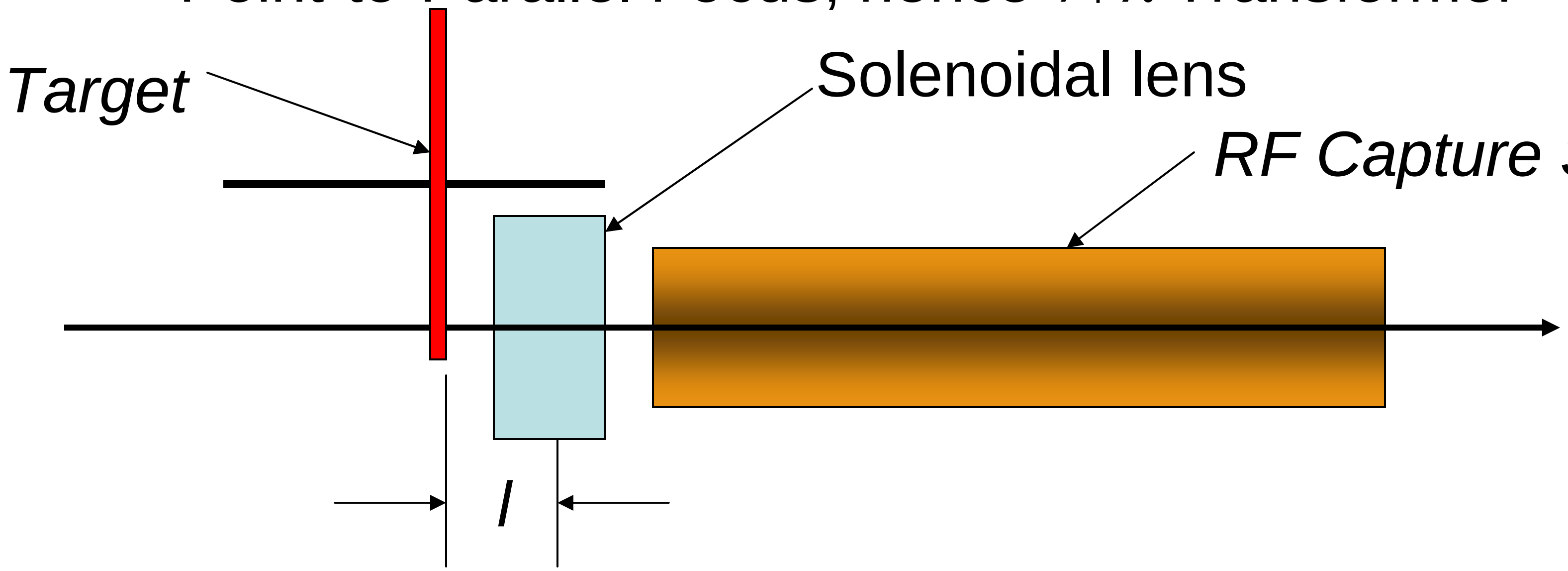
Pulsed Flux Concentrator

Parameter	Brechna	ILC	Units
Field Strength	10	7	T
Pulse Length	40	1	ms
Repetition Rate	1/3	5	Hz

However, there have been no “takers” for a flux concentrator WP. BINP does not believe this is realizable.

DC OMD

Point-to-Parallel Focus, hence ¼ λ Transformer



Magnet "Design": B_0, Length, Aperture, Placement

Capture Efficiency

Magnet Design: Amp-turns, I, V, Cooling, Field Quality

Concerns: dc field on target (eddy currents), capture efficiency

DC OMD

Point-to-Parallel Focus, hence ¼ λ Transformer

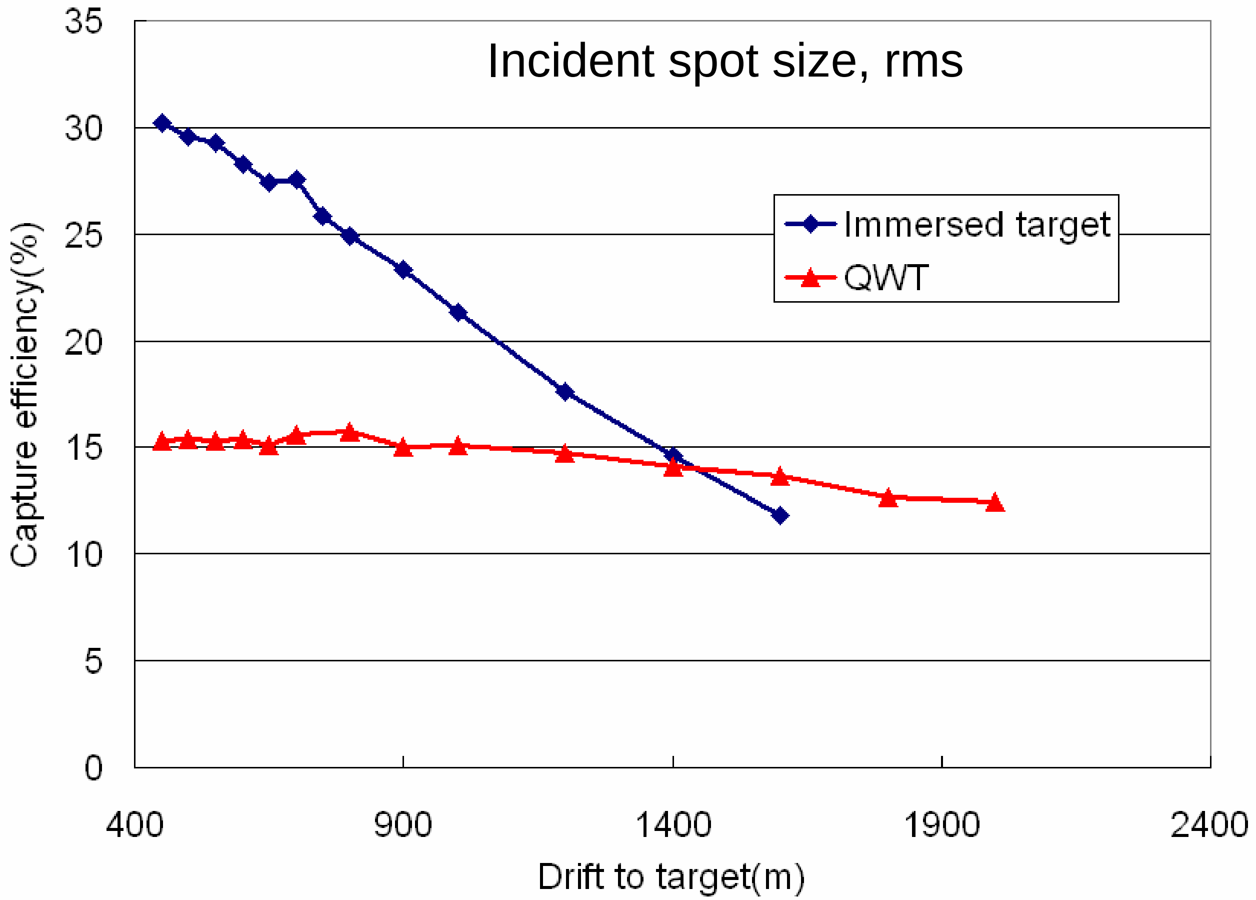
$$\frac{1}{f} = k^2 l = \left(\frac{B_0^2 l_{omd}^2}{4\left(B\rho_0\right)^2} \right) l$$

$$f = l$$

$$k = \left(\frac{B_0 l_{omd}}{2\left(B\rho_0\right)} \right) = \frac{1}{l}$$

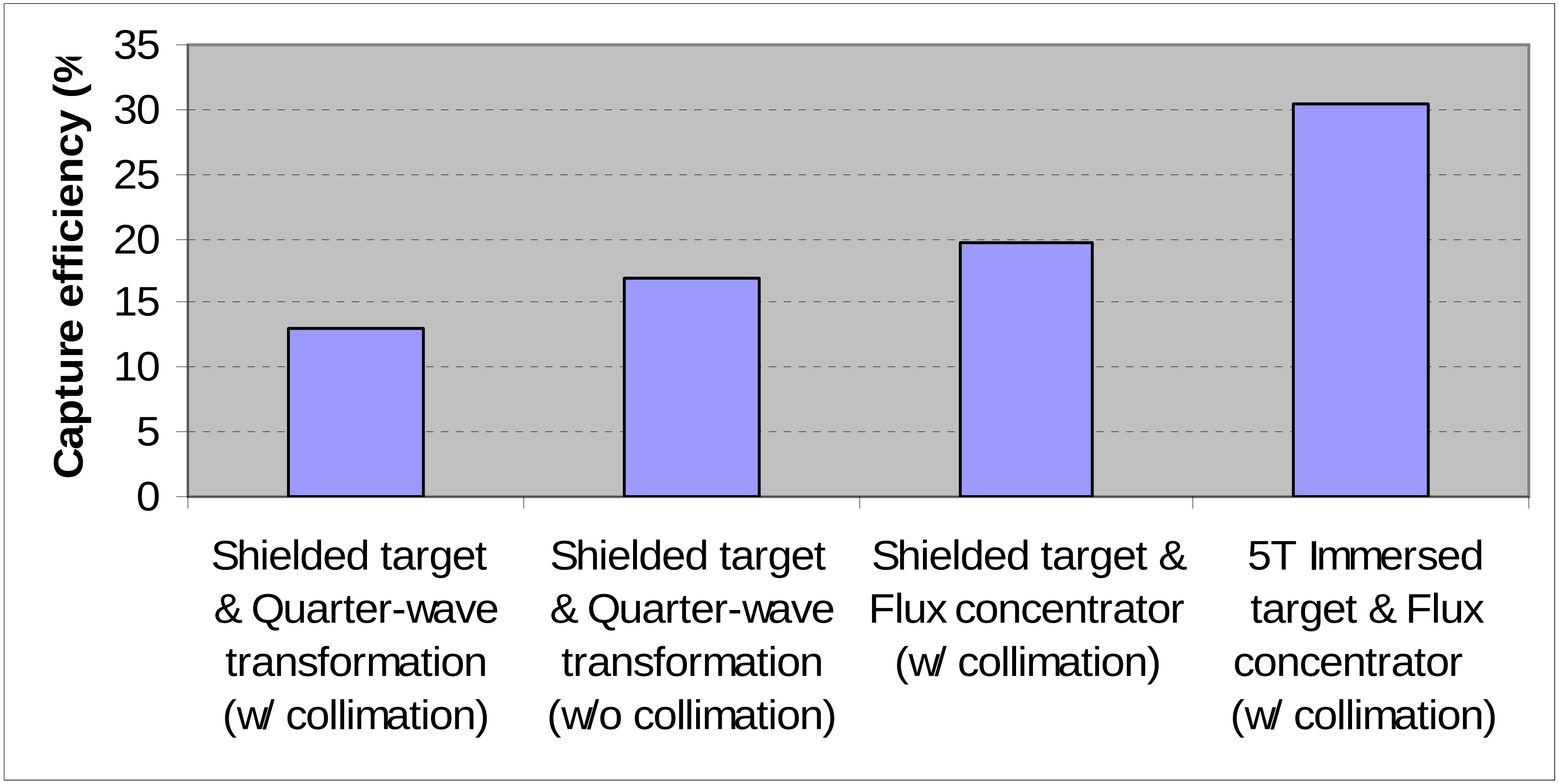
Capture Efficiency: WL ANL

1.4 cm 4.8 cm 8.2 cm



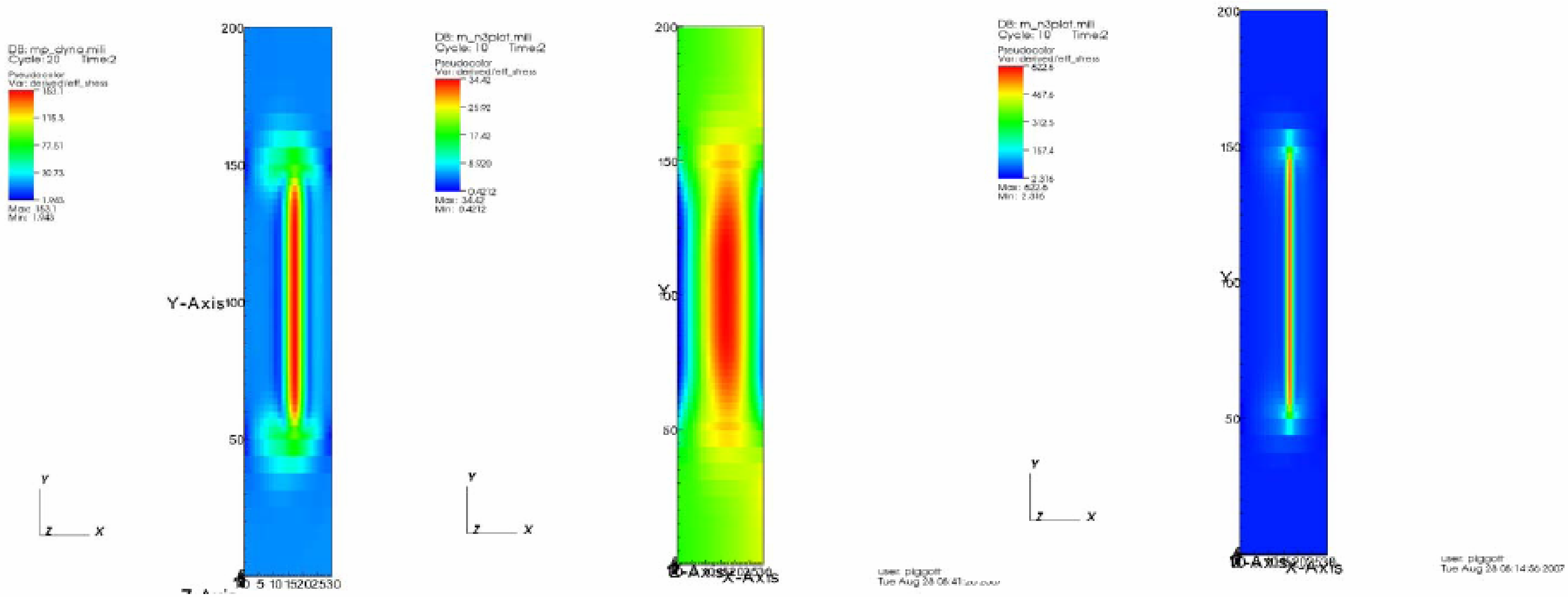
Capture Efficiency: FZ, YN SLAC; WL ANL

Americas



Energy Deposition, TP LLNL

Spot Size Comparisons- von Mises Stress

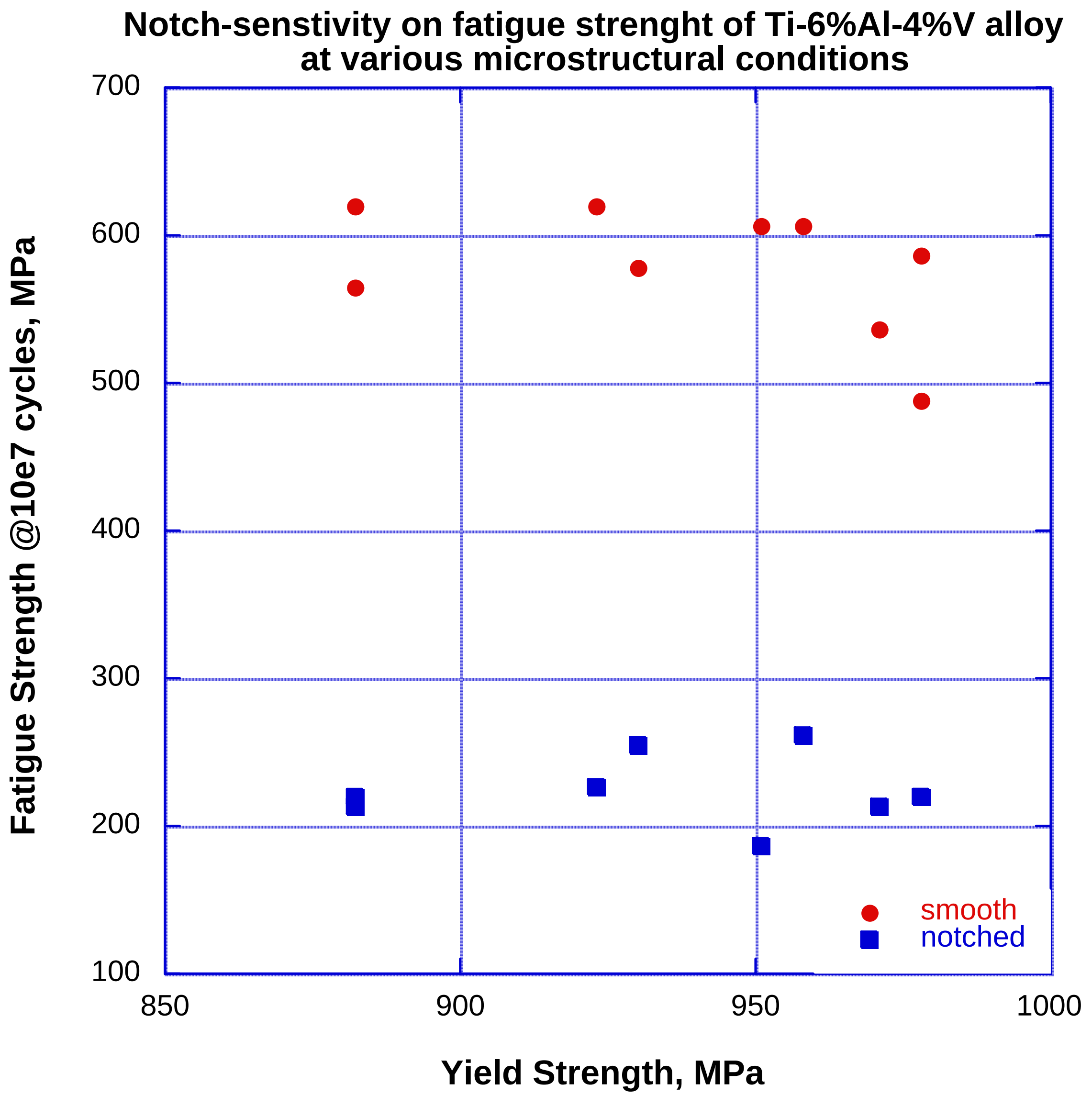


Sigma=1.7 mm
σ_{max}= 153.1 MPa

Sigma=3.4 mm
σ_{max}= 34.42 MPa

Sigma=0.85 mm
σ_{max}= 622.6 MPa

TiAlV fatigue strength, AS LLNL



Sparks:1984

¼ λ XMFR Studies

Ti-alloy and W-Re Target Energy Deposition Numbers

W. Liu, T. Piggott, and J. C. Sheppard

Rev. 7: August 24, 2007

Assuming a gaussian transverse spatial distribution of undulator photons incident to a spinning target annulus of Ti-alloy, what are the values for the deposited energies, energy densities, stresses, and peak and average temperature rises in the target? How do these values change with variations in the incident beam energy and size and tangential target velocity? What is the "safe" engineering limit of the incident beam intensity?

Table 5:

Parameter					Units
Target Material	TiAlV	TiAlV	TiAlV	TiAlV	
Incident Spot Size	1.7	1.7	1.7	1.7	mm
Capture Efficiency	13	16	20	30	%
Number of photons per electron	577	469	375	250	γ/e^-
Undulator Length	303	246	197	131	m
Average power deposition	20	16	13	9	kW
Peak temperature rise	117	95	76	50	^{0}K/pulse
Peak compressive stress, TE	113	92	74	49	MPa

n_γ

Americas

¼ λ XMFR Studies

Table 2:Ti-alloy and W-Re target material comparison, with overhead factor of *f* = 1.5

Parameter	Symbol	Value		Units
Target Material		Ti-alloy	W-Re	
Target thickness	l_t	1.43	0.14	cm
Target absorption	α_T	8	4.1	%
Target yield	Y_γ	2	3.3	% (e^+/γ)
Capture efficiency	ε_c	15	12	%
Number of photons per electron		500	379	γ/e^-
Undulator Length	L_u	263	199	m
Incident photon energy	E_i	43.7	33.1	kJ/pulse
Energy deposition per bunch	δE_b	1.33	0.52	J/bunch
Energy deposition per pulse	ΔE_p	3.5	1.4	kJ/pulse
Average power deposition	ΔP_{avg}	17.5	6.8	kW
Peak absorbed energy per bunch	$\delta U_b/Vol$	5.2	20.3	MJ/m^3-bunch
Peak absorbed energy per bunch	$\delta U_b/Mass$	1.2	1.1	kJ/kg-bunch
Peak absorbed energy per pulse	$\Delta U_p/Mass$	53	49	kJ/kg-pulse
Peak temperature rise	ΔT_p	101	362	^{0}K/pulse
Peak compressive stress, G	ΔP_{cG}	82	1019	MPa
Peak compressive stress, TE	ΔP_{cTE}	98	637	MPa
Ultimate tensile strength	*UTS*	700@500^0	900@1000^{0}C	MPa

¼ λ XMFR Studies

Comparison with EGS4:
Table 3

Parameter	Value EGS		Hand Calculation		Units
Target Material	TiAlV	W-Re	TiAlV	W-Re	
Spot size (σ_x=σ_y)	1.85	1.47	1.85	1.47	Mm, rms
Peak absorbed energy per bunch	2.75	27	2.76	22.4	MeV/cm^3/ γ
Peak absorbed energy per bunch	4.4	32.8	4.4	27.2	MJ/m^3-bunch
Peak absorbed energy per bunch	0.97	1.7	0.98	1.4	kJ/kg-bunch
Peak absorbed energy per pulse	49	67	49	56	kJ/kg-pulse
Peak temperature rise	93	504	93	418	^{0}K/pulse
Peak compressive stress, G	75	1404	75	1167	MPa
Peak compressive stress, TE	90	886	90	736	MPa

Americas

¼ λ XMFR Studies

Comparison with LSDyna3D:
The expressions for the compressive stress, ΔP_{cG} and ΔP_{cTE} , have modified by factors of $1/\pi$ and $(1-2\nu)$, respectively to better "match" the stresses calculated with LS Dyna3D. Table 4 lists the peak compressive stresses for Ti-alloy and W-Re for a given peak temperature rise as estimated by the above expressions and by LSDyna3D. For both the Ti-alloy and W-Re case, the ΔP_{cTE} estimate more closely agrees with the LSDyna3D simulations for a given ΔT_p .
Table 4

Parameter	LSDyna3D		Hand Calculation		Units
Target Material	TiAlV	W-Re	TiAl V	W-Re	
Peak temperature rise	148	504	148	504	^{0}K/pulse
Peak compressive stress, G	163	844	119	1405	MPa
Peak compressive stress, TE			143	887	MPa

Americas

¼ λ XMFR Studies

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¼ λ XMFR Studies

Can design ILC e+ Source w/ ¼ λ XMFR

Capture Yield is in the range of ~13%

Undulator is ~300 m long (vs. 147 in RDR)

Target stresses are acceptable for ~500 m undulator-to-target drift distance

Improved capture efficiency reduces undulator length and target stress

Recommendation: baseline ¼ λ XMFR; develop pulsed flux concentrator