SEMINAR
TECHNISCHER BEREICH

Datum:	Dienstag, den 09.05.2000, 14.00 Uhr
Ort:	DESY Zeuthen, Seminarraum 3
Thema:	**PITZ - Eine allgemeinverständliche Einführung in den Aufbau und die Aufgaben des Photoinjektor-Teststandes**
Vortragender:	F. Stephan (DESY Zeuthen)

Der Photoinjektor Teststand in DESY Zeuthen

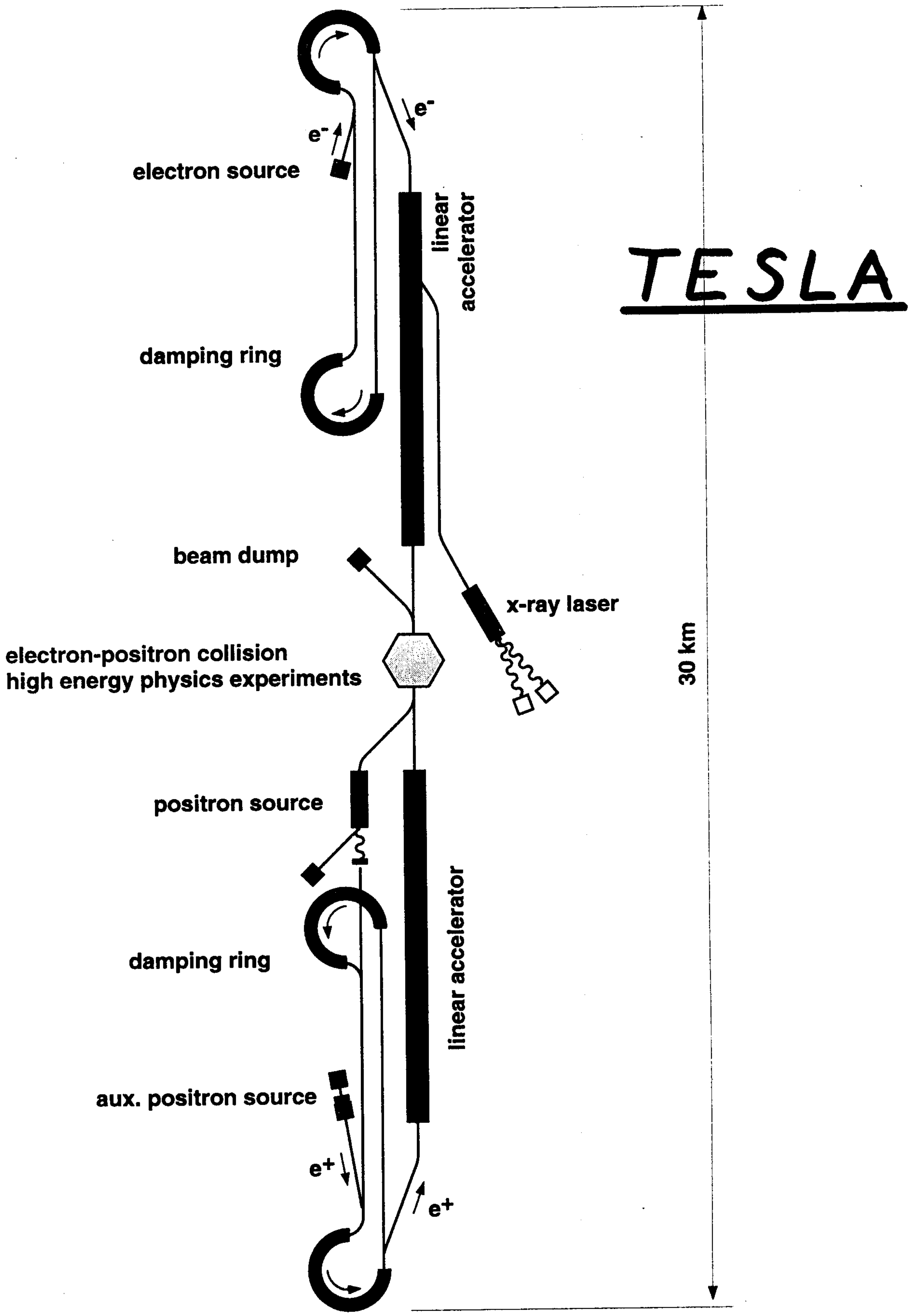
PITZ

Versuch einer allgemeinverständlichen Einführung

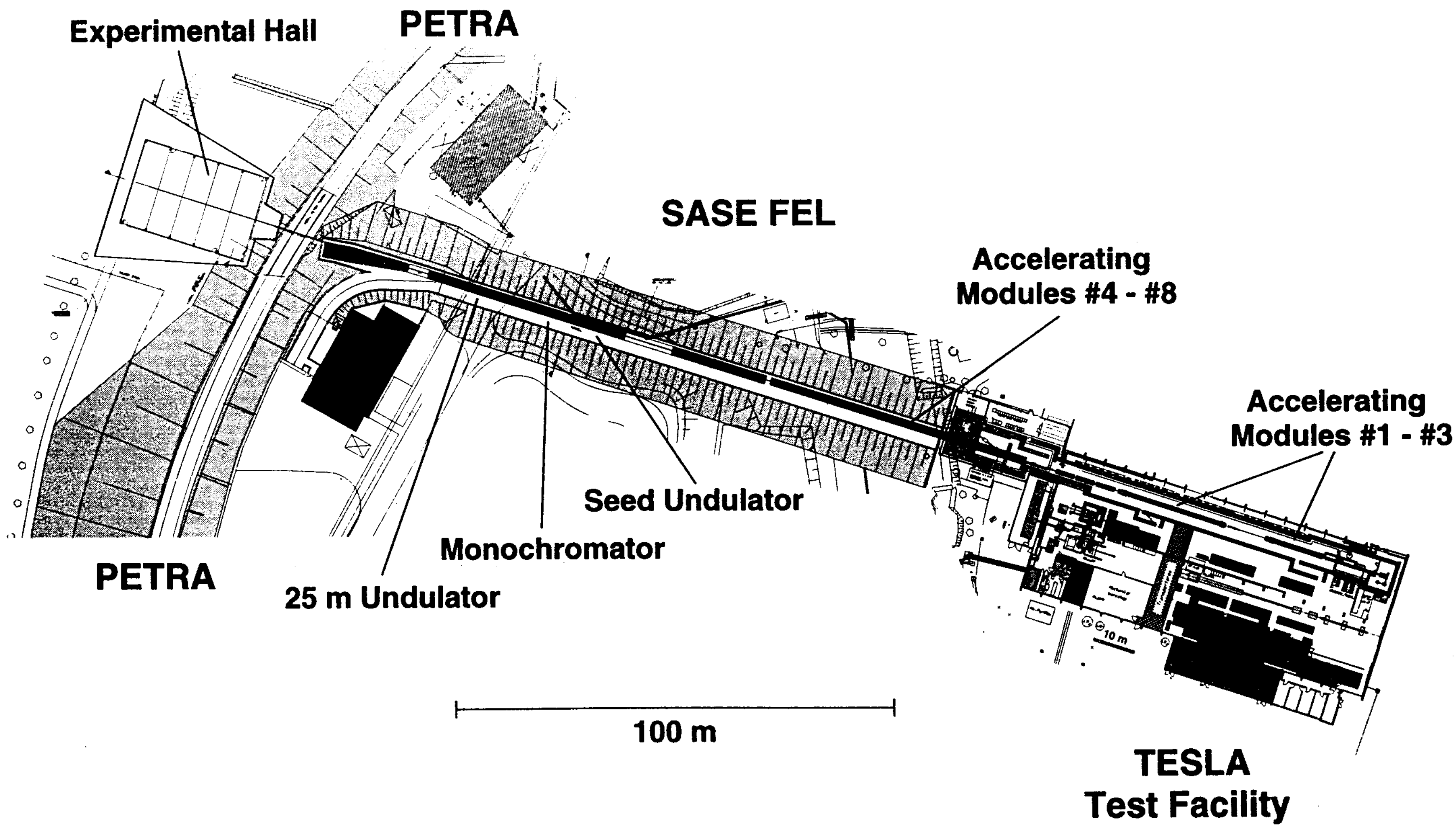
Te. Sem. 9.5.'00

F. Stephan

- TESLA, TTF-FEL, Injektor
- Warum spezieller Injektor für FEL?
- rf gun, Photoeffekt, Aufbau in Phase 1
- das Lasersystem
- Was ist ein Klystron?
- Baumaßnahmen
- ..... ?


TESLA
electron source
e-
e-
linear accelerator
damping ring
beam dump
x-ray laser
electron-positron collision
high energy physics experiments
30 km
positron source
damping ring
linear accelerator
aux. positron source
e+
e+

TTF - FEL

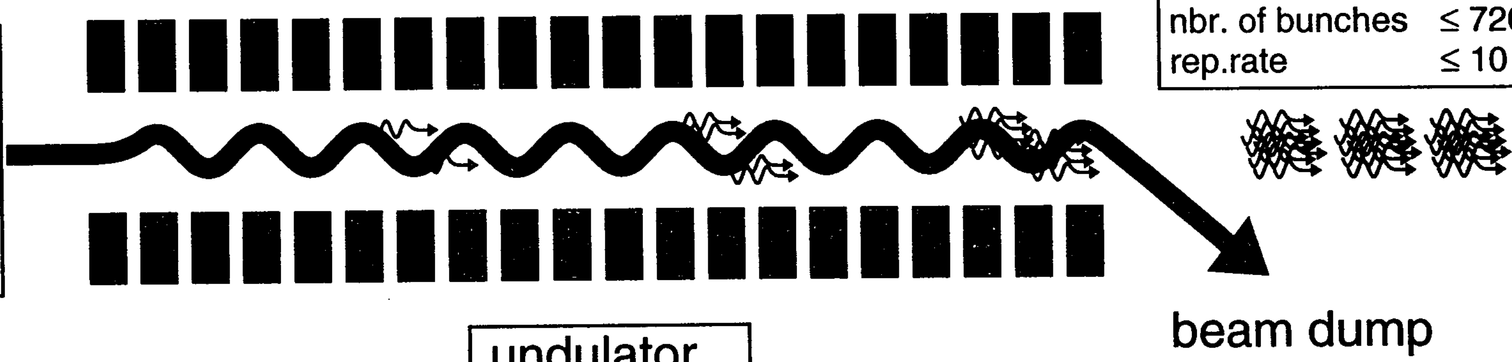


H.Weise 4/99

SASE FEL at the TESLA Test Facility

electron beam

I_{peak} = 2.5 kA
ε_n = 2π mm mrad
σ_z = 0.05 mm
σ_γ/γ = 1.0 ‰
γ = 2000

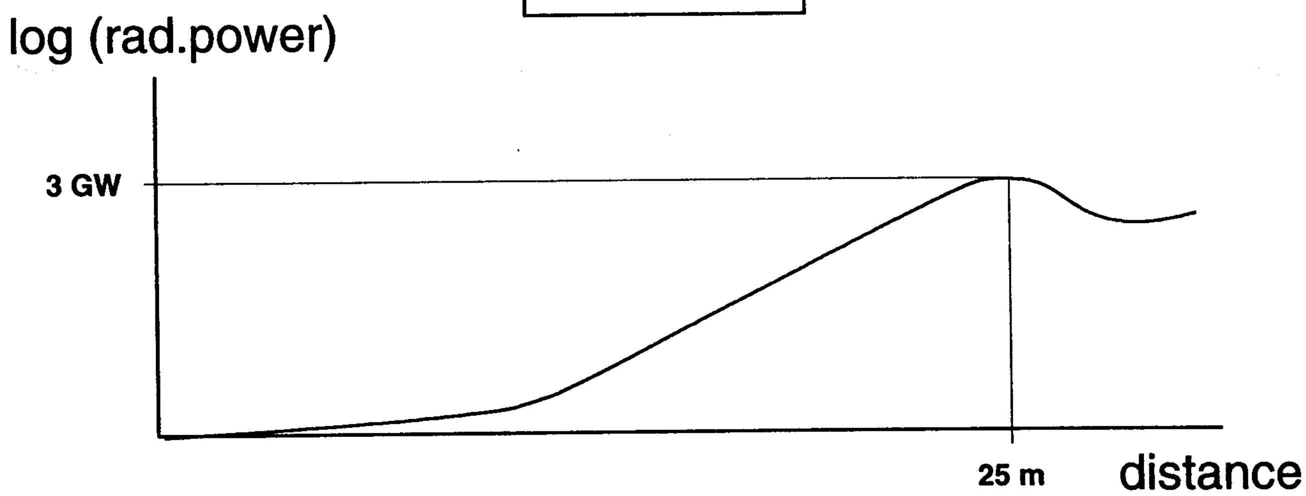


photon beam

λ_{ph} = 6.4 nm (193 eV)
P_{sat} = 3 GW
av.brill. > $10^{21} \frac{\text{photons}}{\text{s (mm mrad)}^2 \text{0.1\% bw}}$
pk.brill. > $10^{29} \frac{\text{photons}}{\text{s (mm mrad)}^2 \text{0.1\% bw}}$
m.p.length = 800 μs
nbr. of bunches ≤ 7200
rep.rate ≤ 10 Hz

undulator

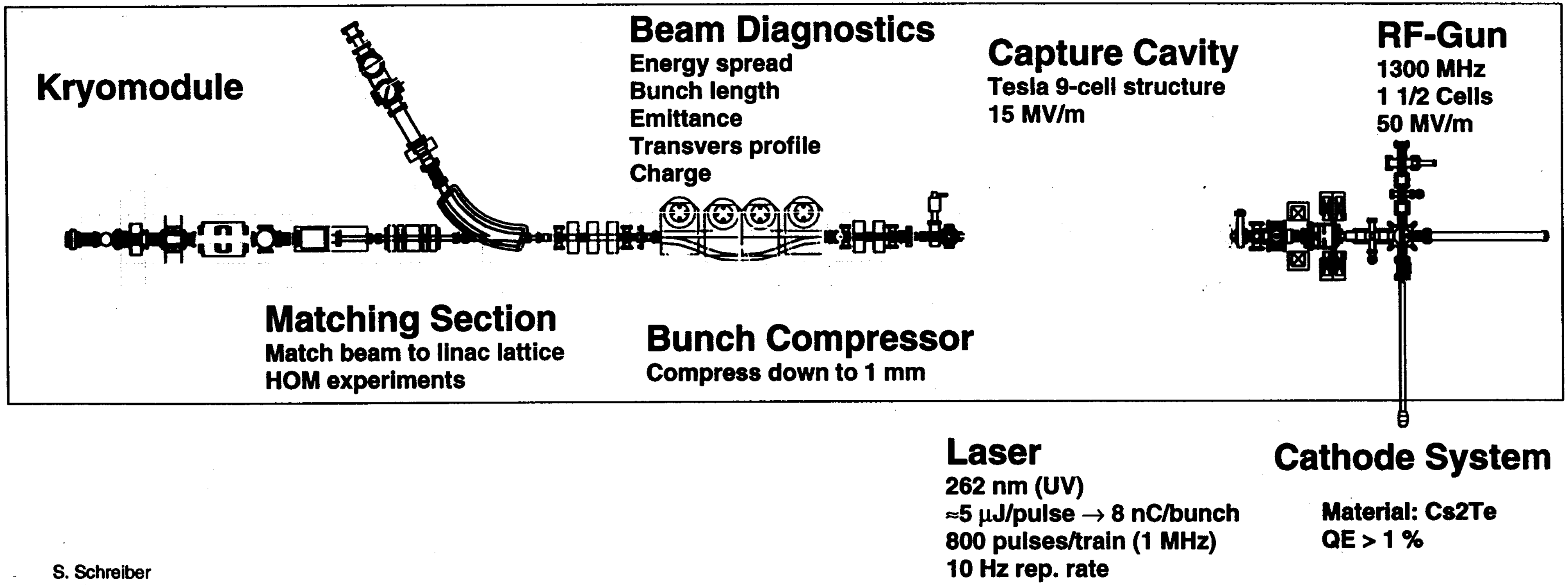
λ_u = 27.3 mm
B_{max} = 0.497 T
N ≈ 1000
gap = 12 mm



H.Weise 04/07/96

TTF Injector II

Train of 800 electron bunches, train length = 0.8 ms
Repetition rate 10 Hz
Bunch charge = 8 nC
Bunch length = 1 mm
Energy = 20 MeV
Emittance (x,y) = 20 π mm mrad



S. Schreiber
14-Jun-1998

Minimum Photon Wavelength

- with $\lambda_u \to 0$ or $\gamma \to \infty$ $\not\Rightarrow$ $\lambda_\gamma \to 0$

because $\lambda_u \to 0$: technically limited

$\gamma \to \infty$: technically limited
and
problems with quantum fluctuations:

with $\gamma \uparrow$ $\Rightarrow$ larger fraction of hard x-rays in spontaneous emission spectrum, interaction with e^- beam
$\Rightarrow$ energy spread (e^-) $\uparrow$

$\Rightarrow E(e^-) \lesssim 25$ GeV

$$\lambda_\gamma^{min}/\text{Å} \approx 4\pi \frac{\varepsilon_n/\text{mrad}\cdot\text{mm}}{\sqrt{I_p/\text{kA} \cdot L_u/\text{m}}} \qquad (0.6 \to 1.0\,\text{Å})$$

ε_n = normalized emittance (~1π mm mrad)

I_p = peak e^- current (~5 kA)

L_u = undulator length ($\lesssim$ 100 m)

What is Emittance?

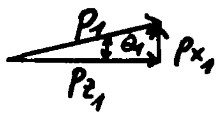
$\varepsilon_t \sim$ (e^- beam size) $\cdot$ (e^- beam angular divergence)

$\varepsilon_l \sim$ (e^- bunch length) $\cdot$ (energy spread of e^- bunch)

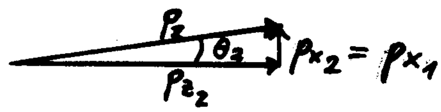
ε = 6d phase space volume

<u>acceleration</u> (adiabatic damping):

before:



after:



$$\theta_2 < \theta_1$$

$\Rightarrow$ angular divergence is reduced

$\Rightarrow$ normalized transverse emittance:

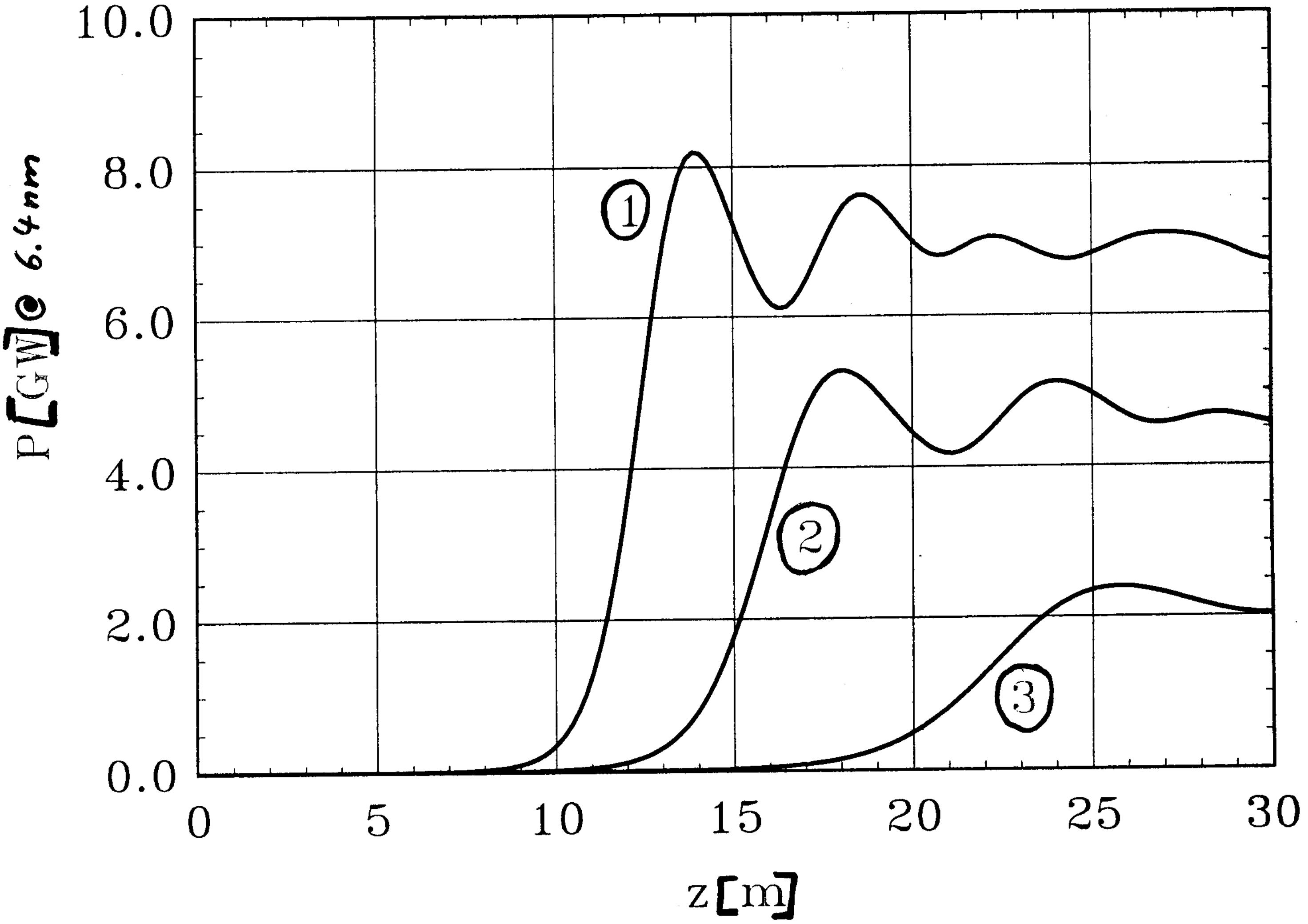
$$\varepsilon_x^n = \beta \cdot \gamma \cdot \sqrt{\sigma_x^2 \cdot \sigma_{x'}^2 - \mathrm{cov}^2(x,x')} \quad ; \beta = \frac{v}{c}, \gamma = \frac{1}{\sqrt{1-\beta^2}}$$

$$x' = \frac{dx}{ds}$$

(is normally conserved)

TTF FEL Phase 2

$\frac{\Delta E_e}{E_e} = 0.1\%$



Dependence of the output radiation power of a FEL on the normalized beam emittance for the example of the TTF FEL at 6.4 nm. The energy width of the electron beam is 0.1 %. The transverse beam emittance is (1) $\epsilon_n = 1 \cdot 10^{-6}$m, (2) $\epsilon_n = 2 \cdot 10^{-6}$, (3) $\epsilon_n = 4 \cdot 10^{-6}$m.

- high gain FELs need:

  - beam charge ↑
  - bunch length ↓
  - energy spread ↓
  - emittance ↓
  - spot size ↓

  } strongly coupled

  at linac: beam parameters mainly defined at injector

  ⇒ specialized photo injector

  (TTF-FEL user facility starting from 2003)

- TESLA needs:

  - high luminosity
  - small bremsstrahlung at IP

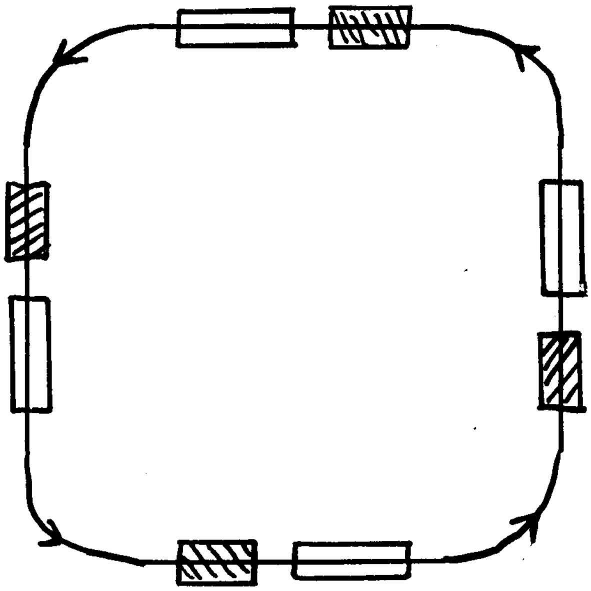
  ⇒ flat $e^{\pm}$ beams

  ↑ for e^-: realization with photo injector

  - for polarized + unpolarized beams

  ⇒ get rid of damping ring for e^-

Radiation Damping in Synchrotrons

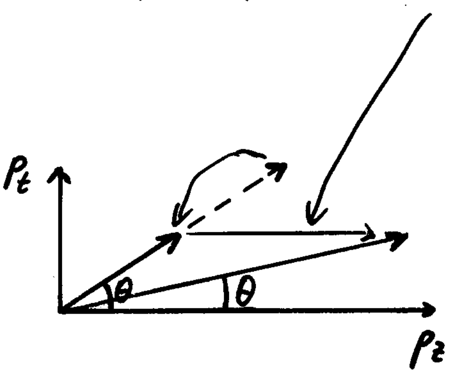


▨ radiation damping [wiggler, (foil), synchrotron rad., ...]

⇒ energy loss (reduction of 3D momentum)

▭ accelerating structure

⇒ energy gain (gain, replace longitudinal momentum)



RF Photoinjectors and related Topics

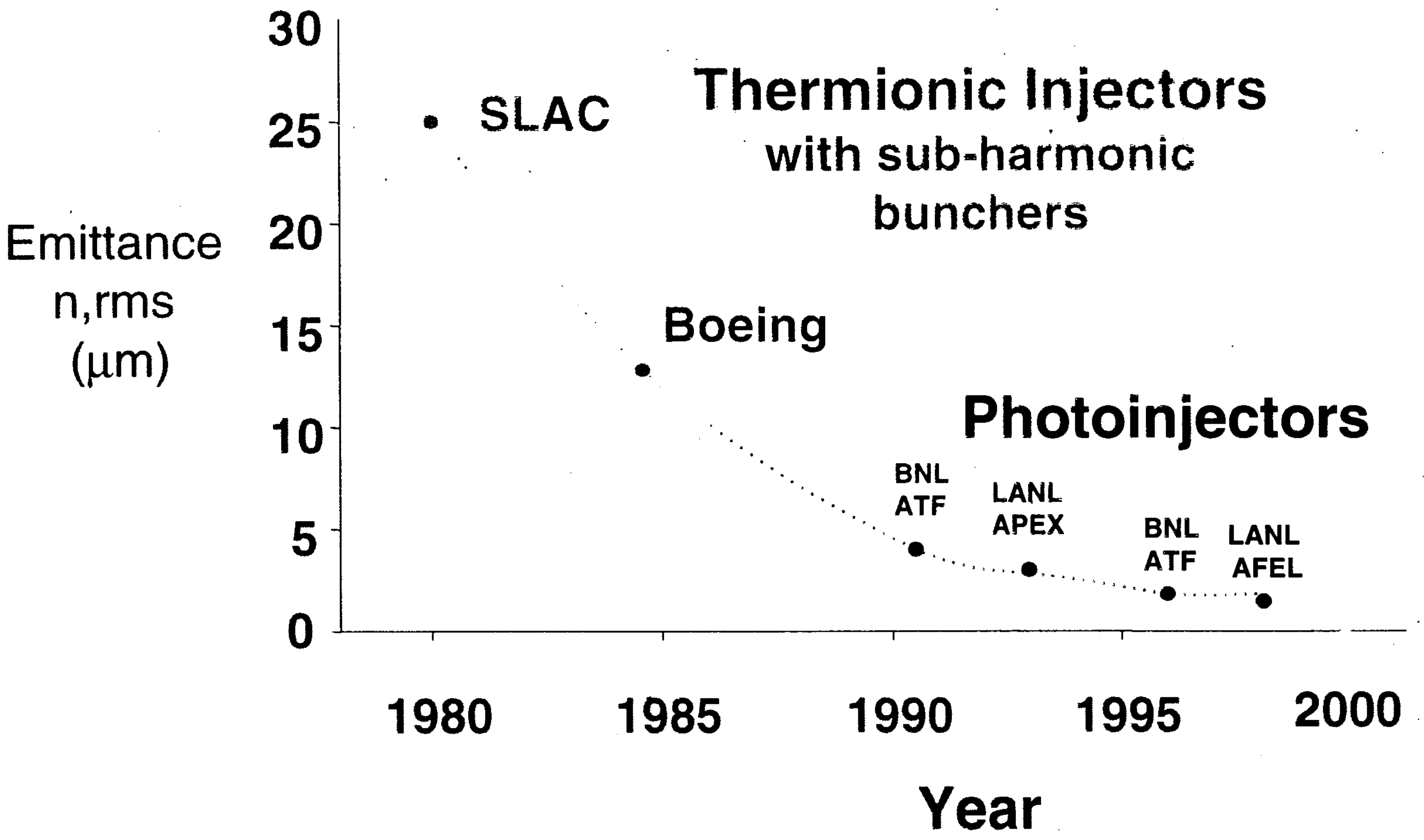
Patrick G. O'Shea
Institute for Plasma Research
Department of Electrical and Computer Engineering
University of Maryland

The 2nd ICFA Advanced Accelerator Workshop on
The Physics of High Brightness Beams

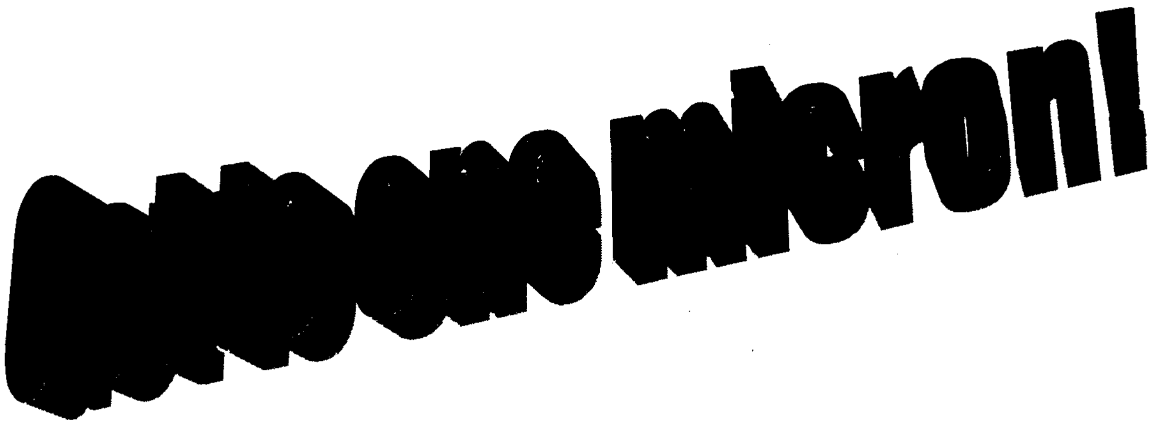
UCLA

November 9, 1999

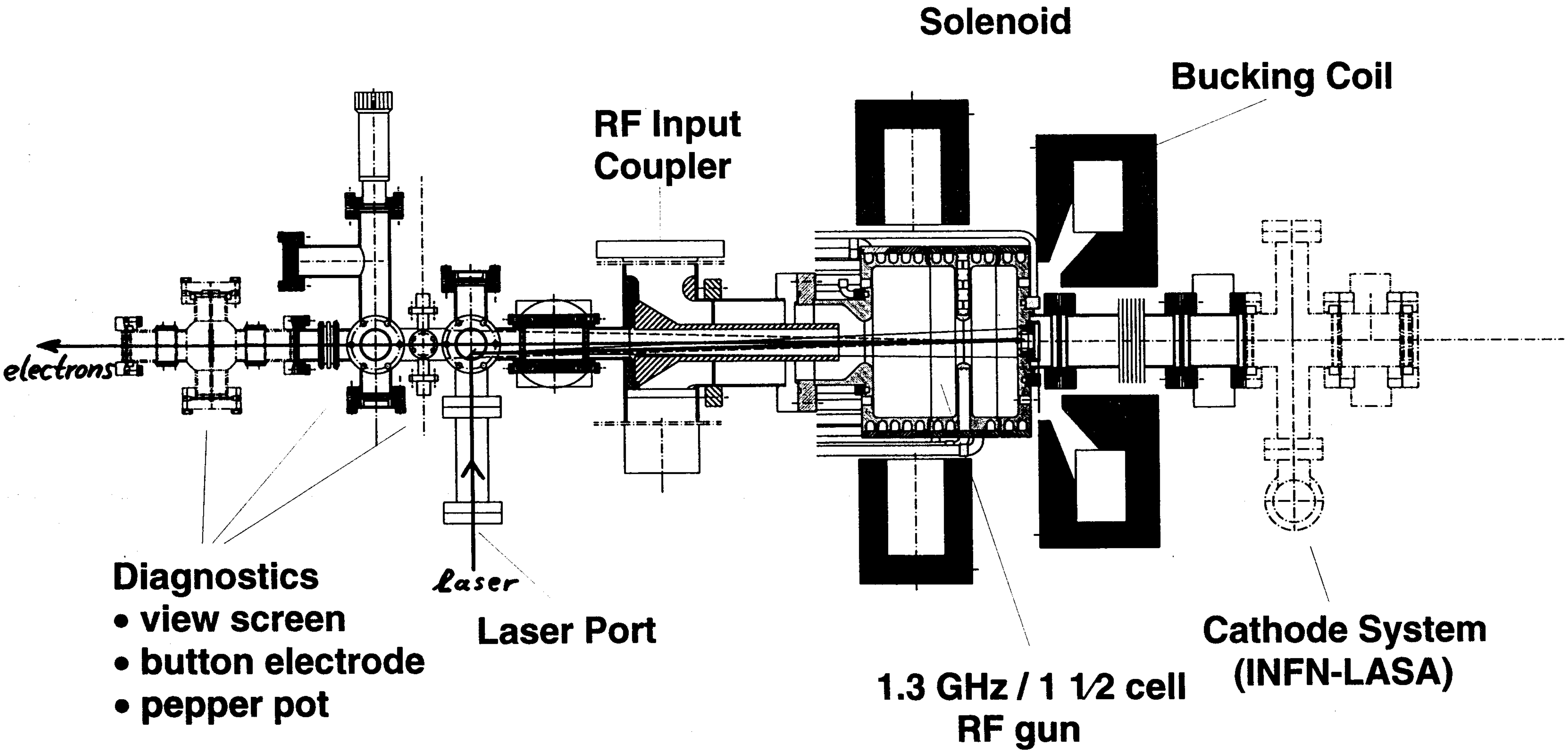
Improvement in emittance over the past twenty years (1 nC bunch, Multi-MeV energy)



Suggestions for future work:

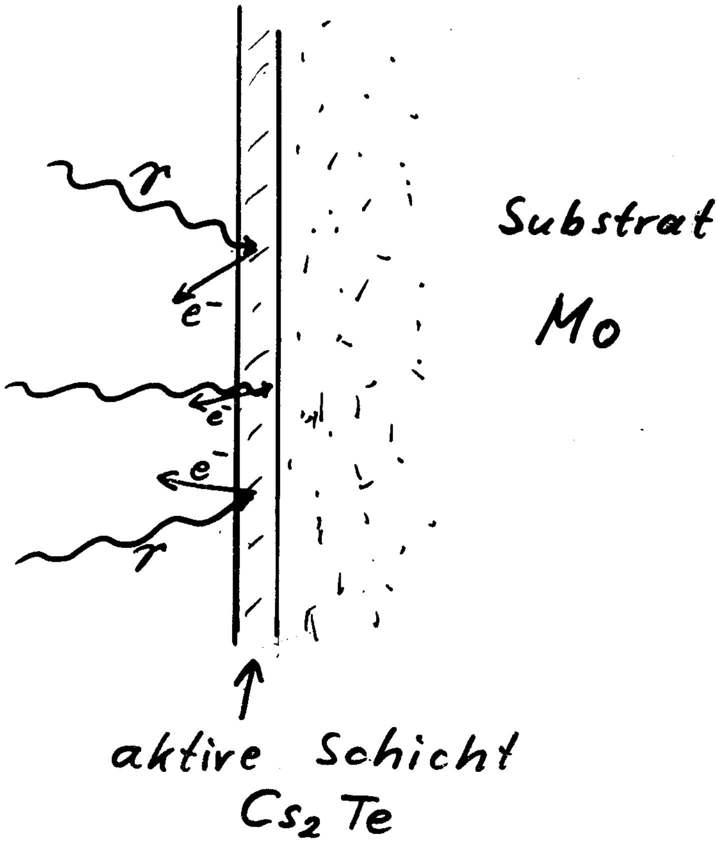


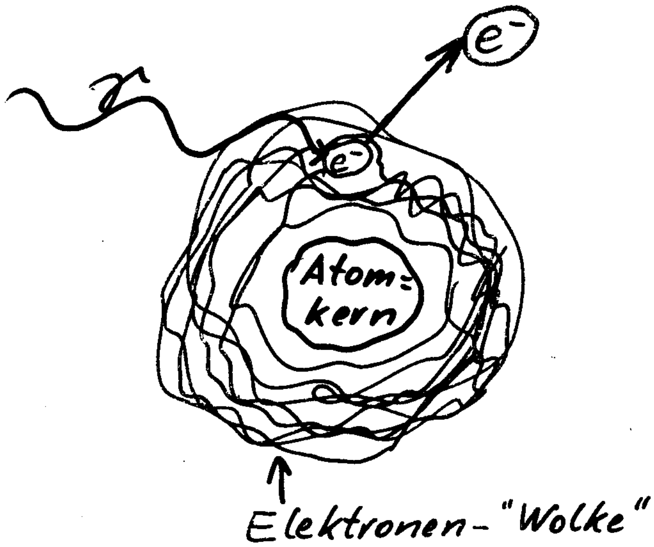
TTF / FEL RF Gun - Under Construction at DESY



H.Weise 16.06.97

Photoeffekt





thermische Emittanz:

- Fläche = Emissionsfläche (Laserspot)
- Winkelverteilung = endlich, aus E_γ und Bandstruktur der aktiven Schicht

$\varepsilon \sim 0{,}5\ \pi$ mm mrad

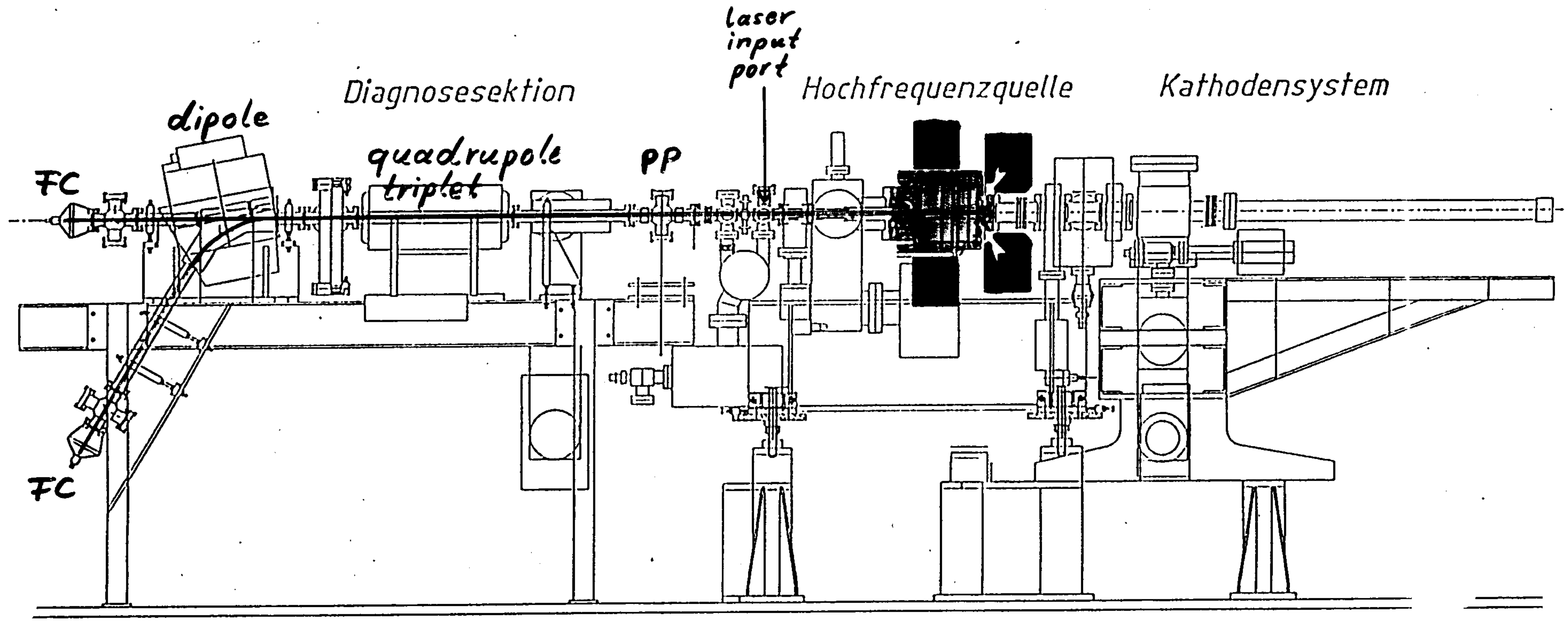
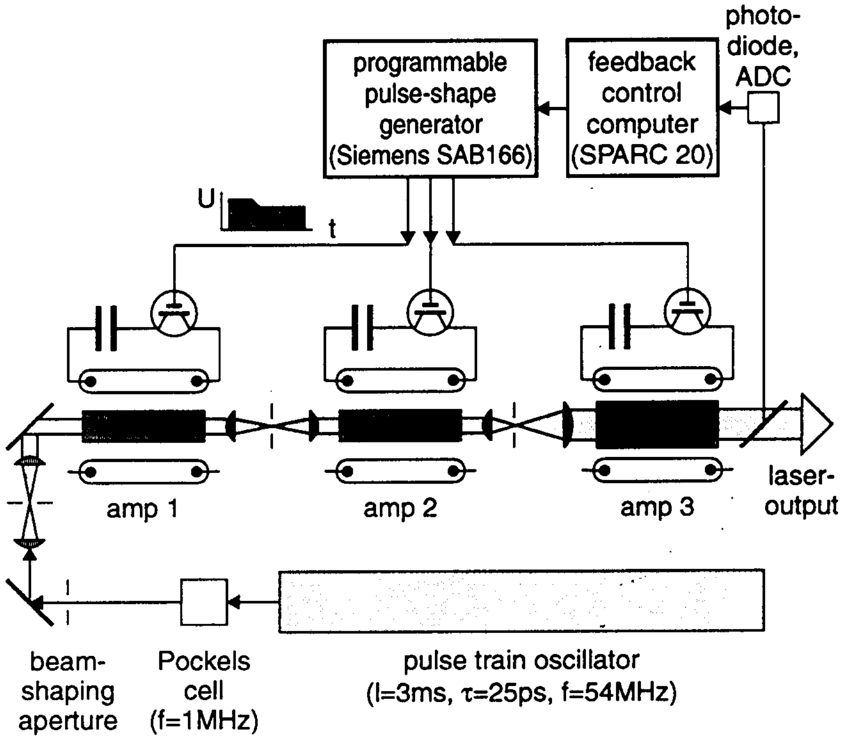
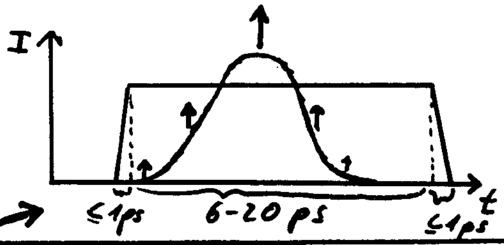


Fig. 8: The test stand for rf electron sources at DESY (length about 5m).


programmable
pulse-shape
generator
(Siemens SAB166)
feedback
control
computer
(SPARC 20)
photo-
diode,
ADC
U
t
amp 1
amp 2
amp 3
laser-
output
beam-
shaping
aperture
Pockels
cell
(f=1MHz)
pulse train oscillator
(l=3ms, τ=25ps, f=54MHz)

Max - Born - Institute, Berlin



pulse length	6-20 ps FWHM
shape of the micropulses	rectangular, with short rising and falling edges
new demand on the rising edge of the micropulses	<1 ps
wavelength (ultraviolet)	$\lambda = 260$ nm
energy per micropulse in the ultraviolet	20 µJ (at 1 MHz)
energy per macropulse train in the ultraviolet	160 mJ
length of the macropulse train	800 µs maximum
repetition rate of the micropulses	1 MHz and 9 MHz
repetition rate of the makropulse trains	5...10 Hz

Table 1: Design parameters of the photocathode laser

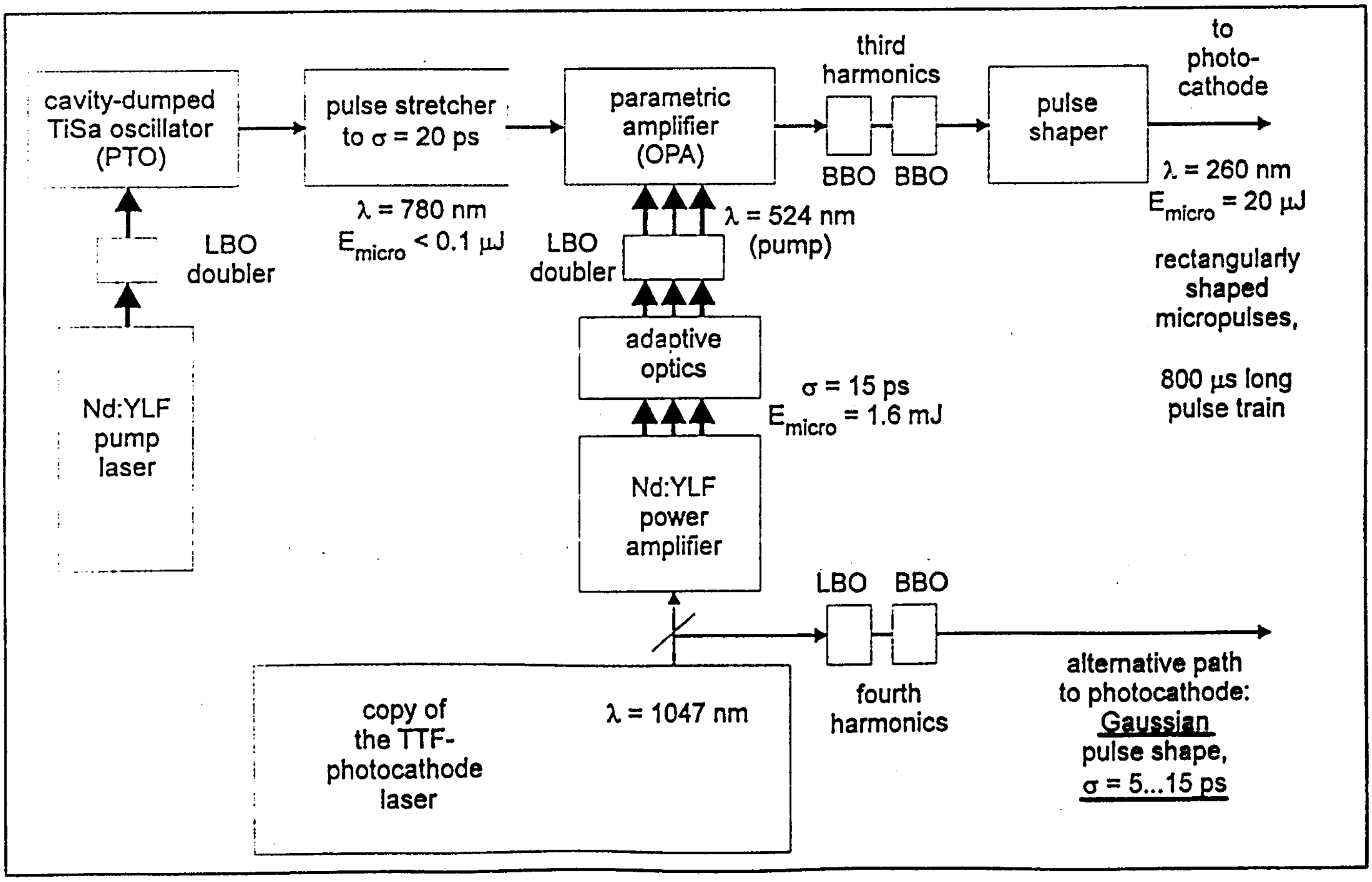
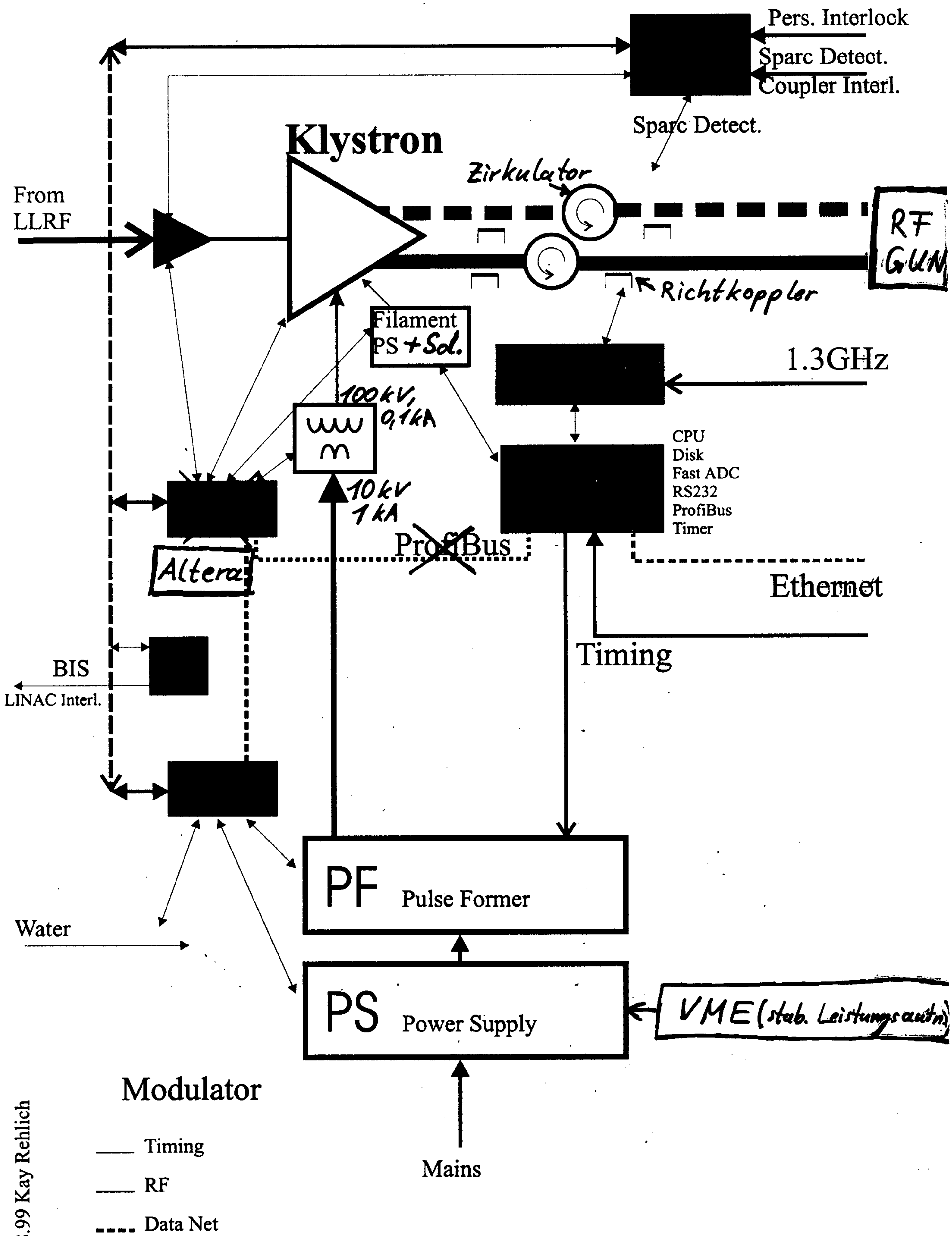


Fig. 7: Principle scheme of the photocathode laser for the test stand



Klystron/Modulator Building Blocks

31.8.99 Kay Rehlich

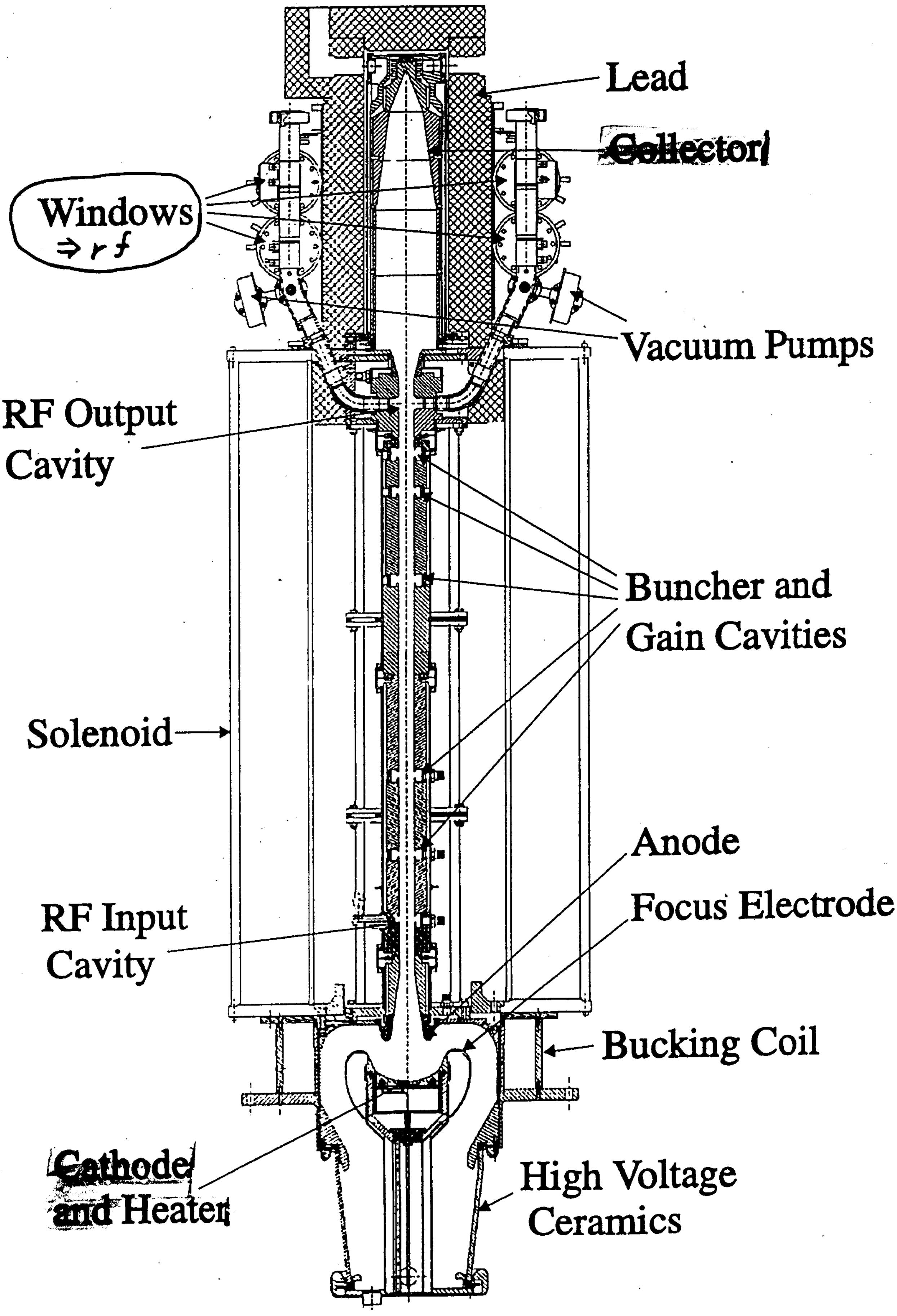


Figure 4.2.23: *150 MW S-Band klystron for the* *S-Band test facility* *(Klystron 1)*

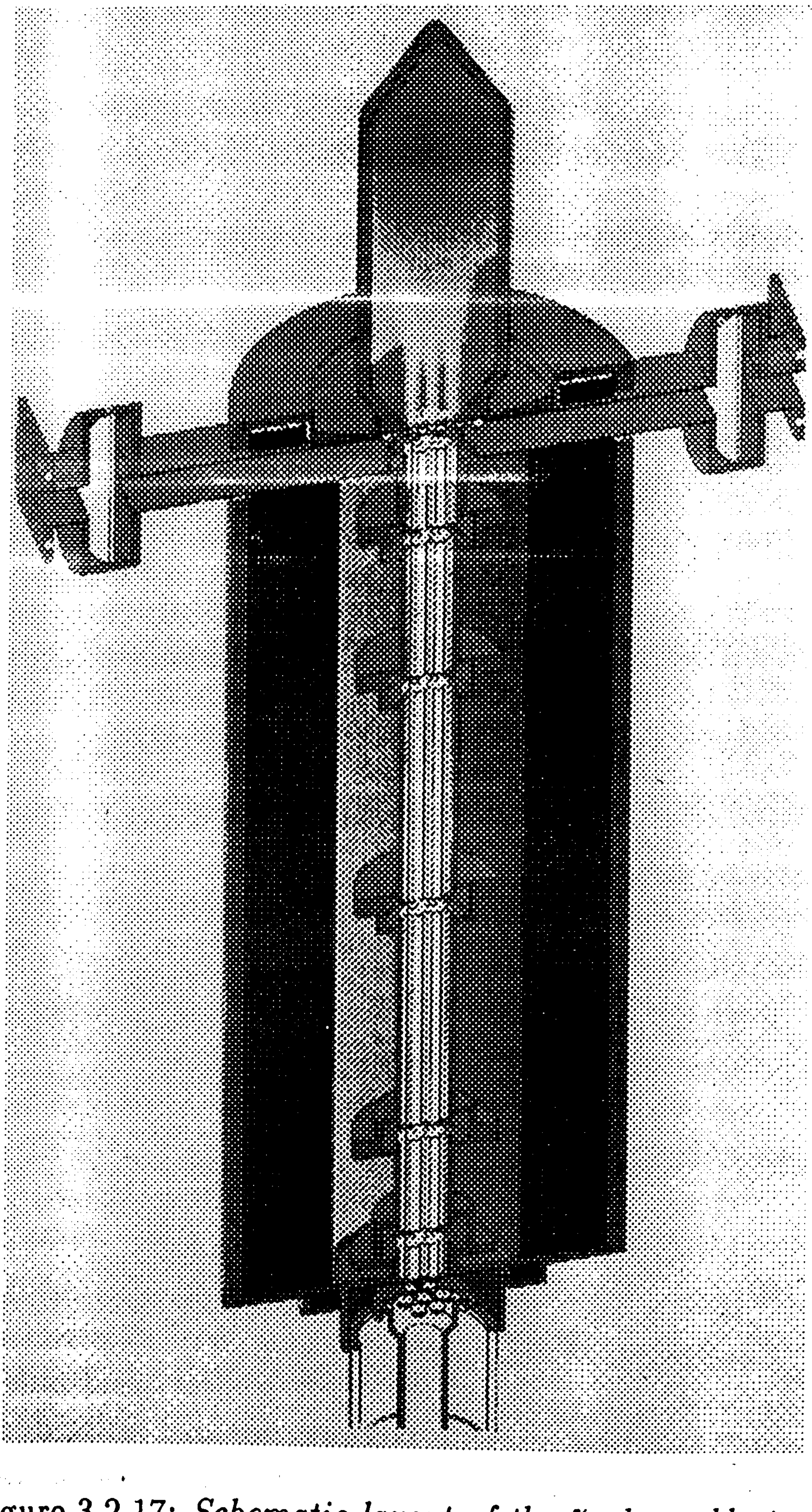
	Design	Tube 1	Tube 2
Power Out	150 MW	153 MW	150 MW
Pulse Duration	3 μs	3 μs	3 μs
Repetition Rate	60 Hz	60 Hz	60 Hz
Average Power	27 kW	27.5 kW	27 kW
Beam Voltage	535 kV	527 kV	508 kV
Beam Current	700 A	680 A	652 A
Perveance	1.79×10^{-6} A/V$^{3/2}$	1.78×10^{-6} A/V$^{3/2}$	1.80×10^{-6} A/V$^{3/2}$
Efficiency	40 %	43 %	45 %
Gain	50 dB min	56 dB	57 dB

Table 4.2.4: *Design and measured parameters of the 150 MW klystrons for the S-Band test facility*

Both klystrons, tube 1 and 2, will be used at the S-Band test facility at DESY. The first tube is already in operation. Figure 4.2.23 shows tube 1. The total height is

1.

10 MW, L-band (1.3 GHz)



2 rf output windows (2×5 MW)

length: ~2.5m

[+ sol. 1.5m
+ tank 1.0m
+ fixing } ~1.0m
+ ...
= 6.0m

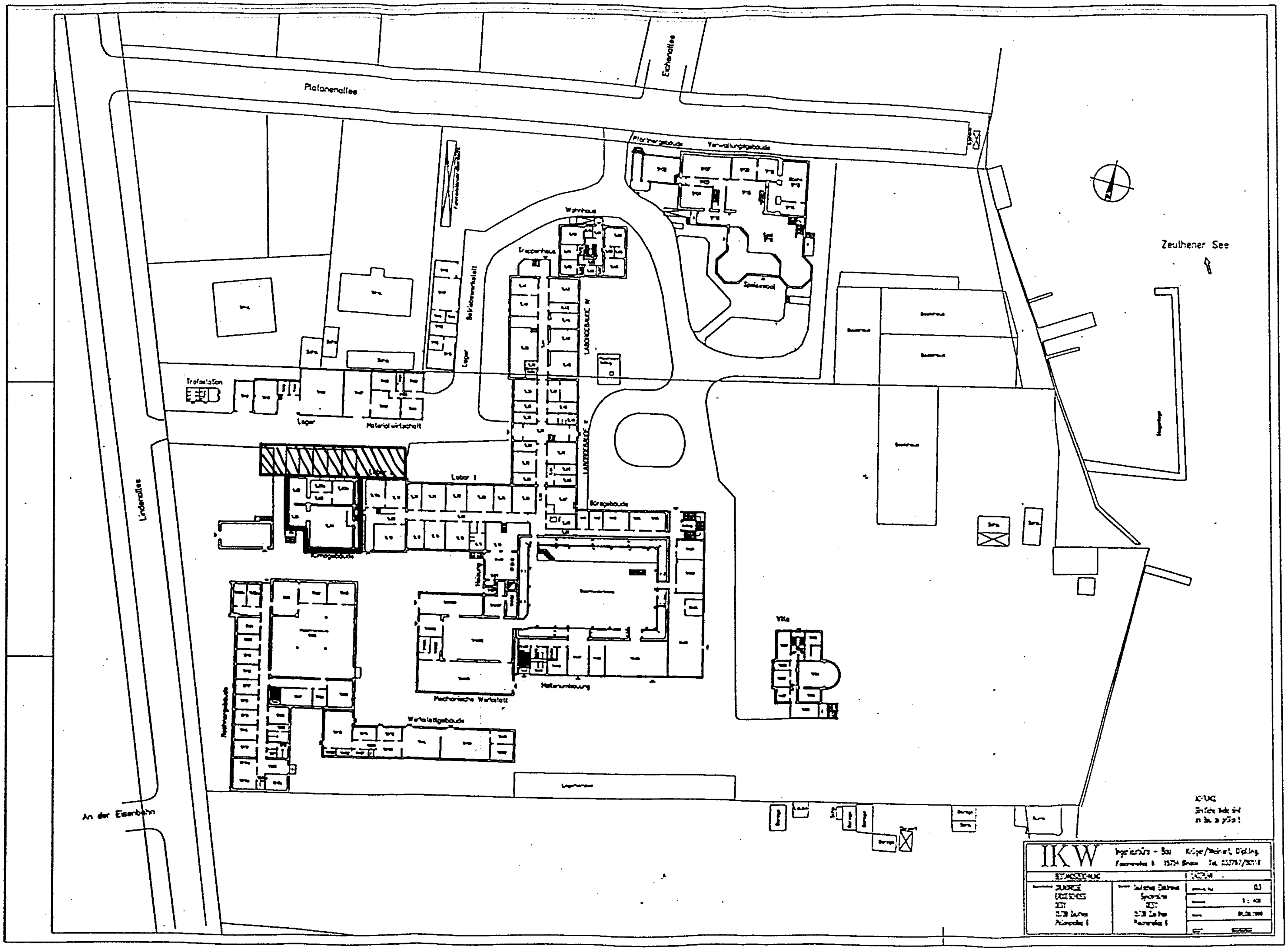
Figure 3.2.17: *Schematic layout of the 7 - beam klystron.*

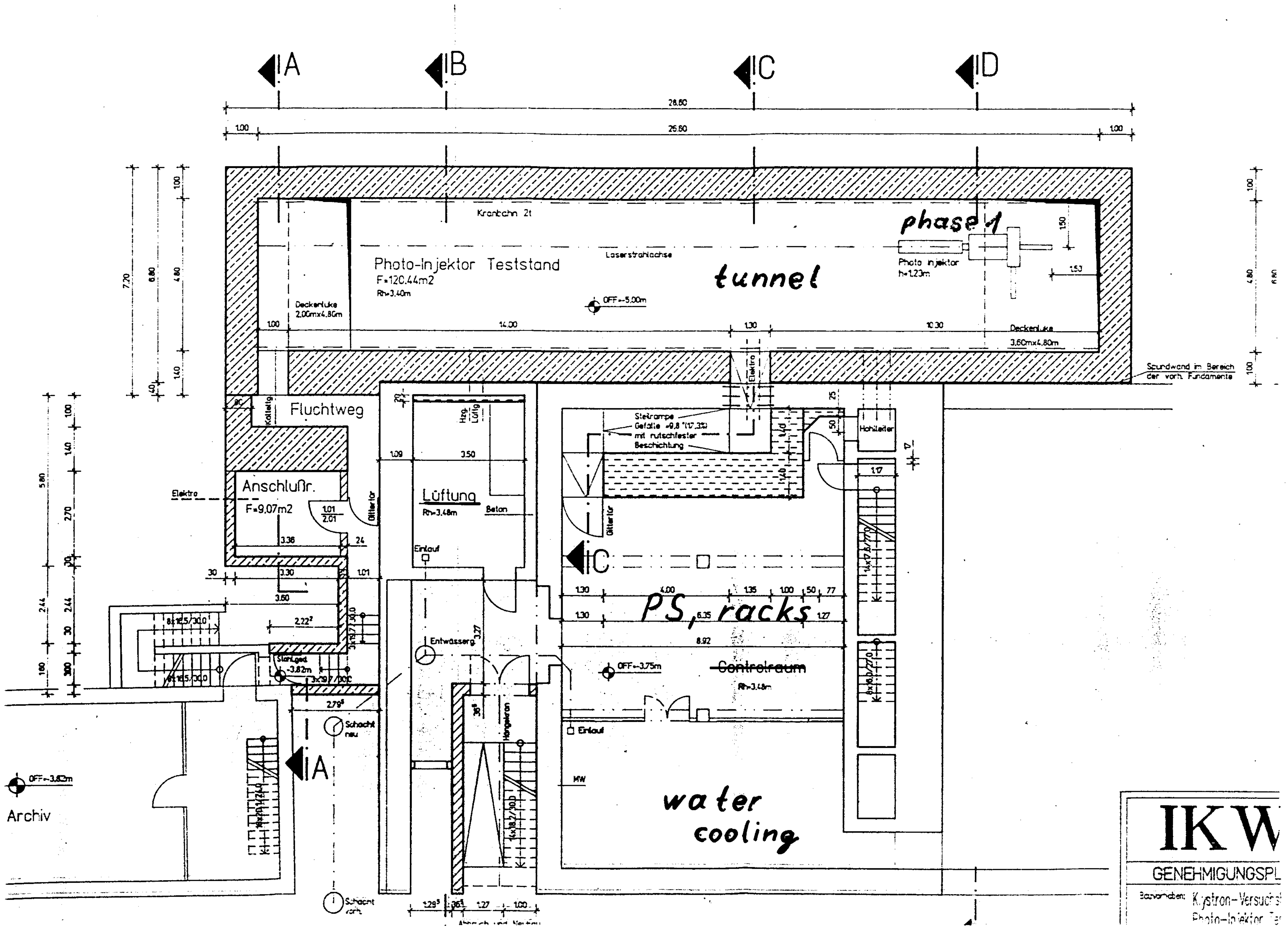
The klystron 1 dB bandwidth is 3 MHz. This is more than adequate for the p-
hase and amplitude regulation loops.

Frequency:	1300 MHz	
RF Pulse length:	1500 μs	
Repetition rate:	10 Hz	
Beam Voltage:	110 kV	
Beam Current (total):	130 A	
Perveance per beam:	$0.5 \cdot 10^{-6}$	
Drive Power:	200 W max.	
Output Power:	10 MW peak	150 kW average
Body Dissipation:	15 kW max.	
Efficiency:	> 70 %	
Gain:	48 dB	
Bandwidth (1 dB):	3 MHz min.	
No. of beams:	7	

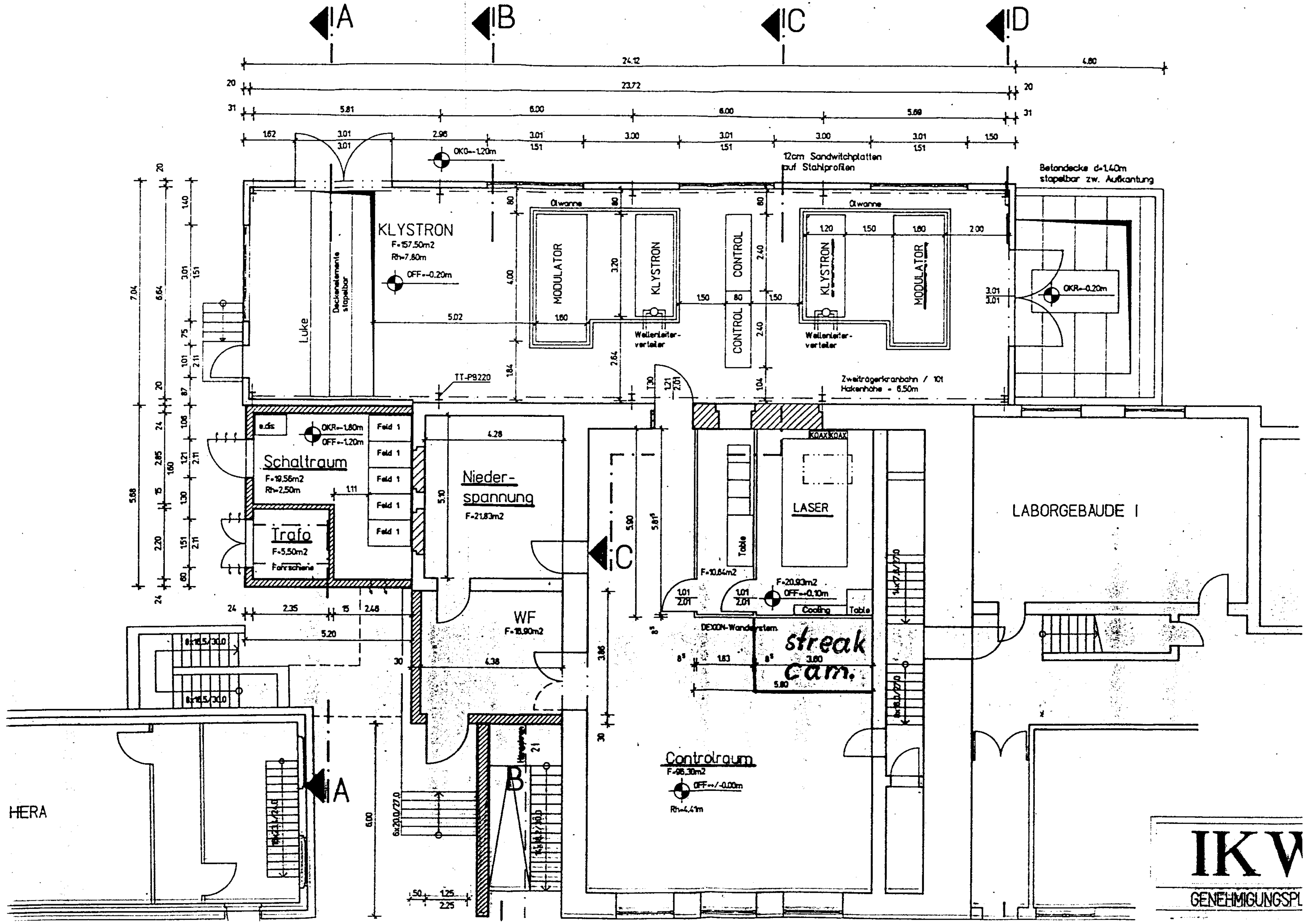
Table 3.2.10: *Design parameters of the Thomson multibeam-klystron*

The gain of 48 dB means that the driver power is below 160 W. This power can

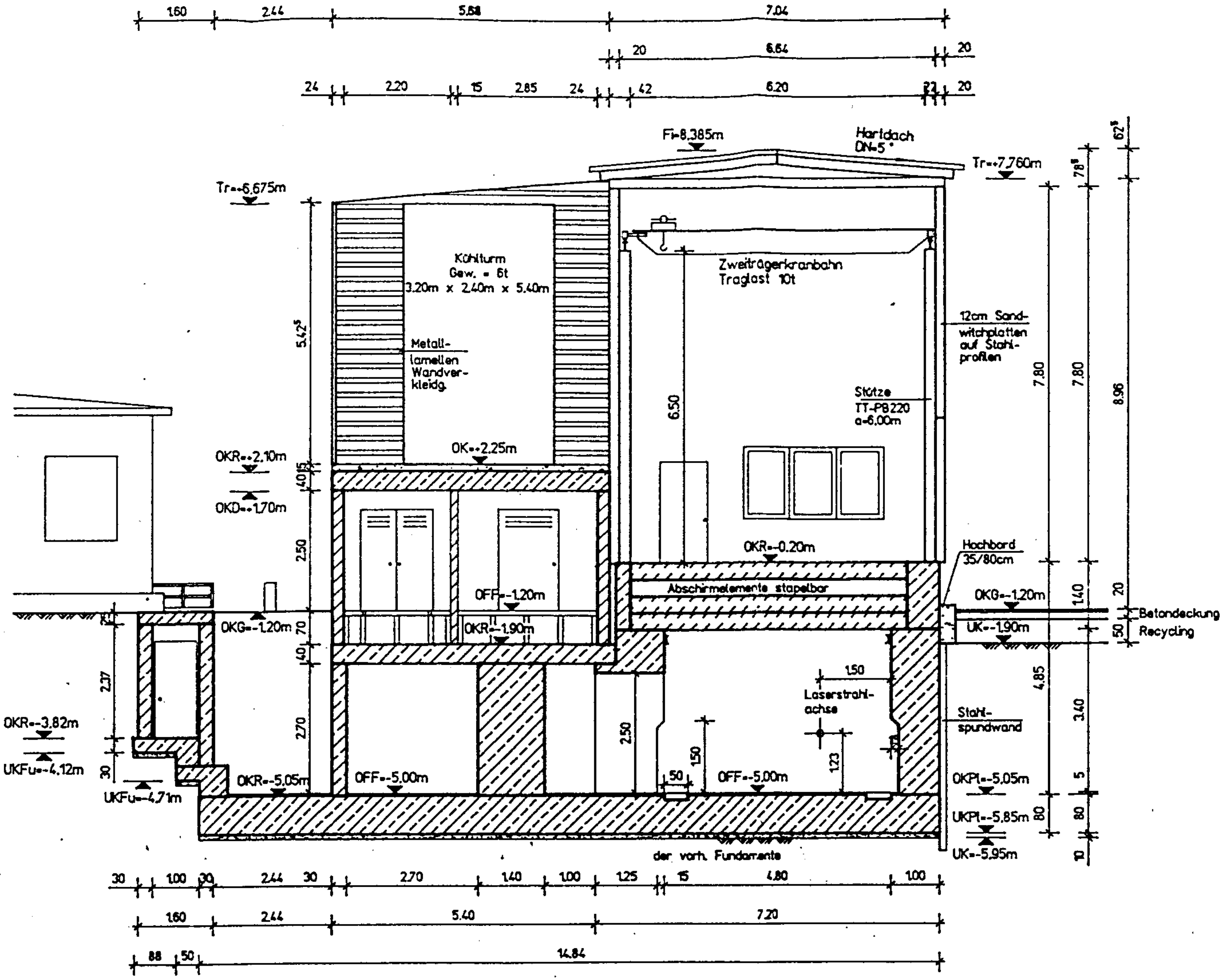

Platanenallee
Eichenallee
Pförtnergebäude
Verwaltungsgebäude
Wohnhaus
Treppenhaus
Speisesaal
Zeuthener See
Betriebswerkstatt
Lager
Trafostation
Materialwirtschaft
Labor I
Bürogebäude
Heizung
Villa
Mechanische Werkstatt
Hallenumbauung
Werkstattgebäude
Lindenallee
An der Eisenbahn
IKW
03



A
B
C
D
28.60
25.60
Kranbahn 2t
phase 1
Laserstrahlachse
Photo-Injektor Teststand
F=120.44m2
Rh=3.40m
tunnel
Photo injektor
h=1.23m
OFF=-5.00m
Deckenluke
2.00mx4.80m
Deckenluke
3.60mx4.80m
Schallwand im Bereich
der vorh. Fundamente
Fluchtweg
Kalteltg.
Elektro
Steilrampe
Gefälle =9.8 °(17.3%)
mit rutschfester
Beschichtung
Hohlleiter
Anschlußr.
F=9.07m2
Lüftung
Rh=3.48m
Beton
Hzg.
Lüftg.
Gittertür
Einlauf
Entwässerg.
PS, racks
Controlraum
OFF=-3.75m
Rh=3.48m
Stahlged.
-3.82m
Schacht
neu
Hängekran
MW
water
cooling
OFF=-3.82m
Archiv
Schacht
vorh.
IKW
GENEHMIGUNGSPL
Bauvorhaben: Klystron-Versuchs
Photo-Injektor Te



A
B
C
D
KLYSTRON
F=157,50m2
Rh=7,80m
OFF=-0,20m
OKG=-1,20m
12cm Sandwitchplatten auf Stahlprofilen
Betondecke d=1,40m stapelbar zw. Aufkantung
Ölwanne
MODULATOR
KLYSTRON
CONTROL
CONTROL
KLYSTRON
MODULATOR
Wellenleiter-verteiler
Wellenleiter-verteiler
OKR=-0,20m
Luke
Deckenelemente stapelbar
TT-P9220
Zweiträgerkranbahn / 10t
Hakenhöhe = 6,50m
Schaltraum
F=19,56m2
Rh=2,50m
OKR=-1,80m
OFF=-1,20m
Feld 1
Trafo
F=5,50m2
Fahrschiene
Nieder-spannung
F=21,83m2
WF
F=18,90m2
LASER
Table
KOAX
F=10,64m2
F=20,93m2
OFF=-0,10m
Cooling
DEXION-Wandsystem
streak cam.
LABORGEBÄUDE I
Controlraum
F=96,30m2
OFF=+/-0,00m
Rh=4,41m
HERA
IKV
GENEHMIGUNGSPL



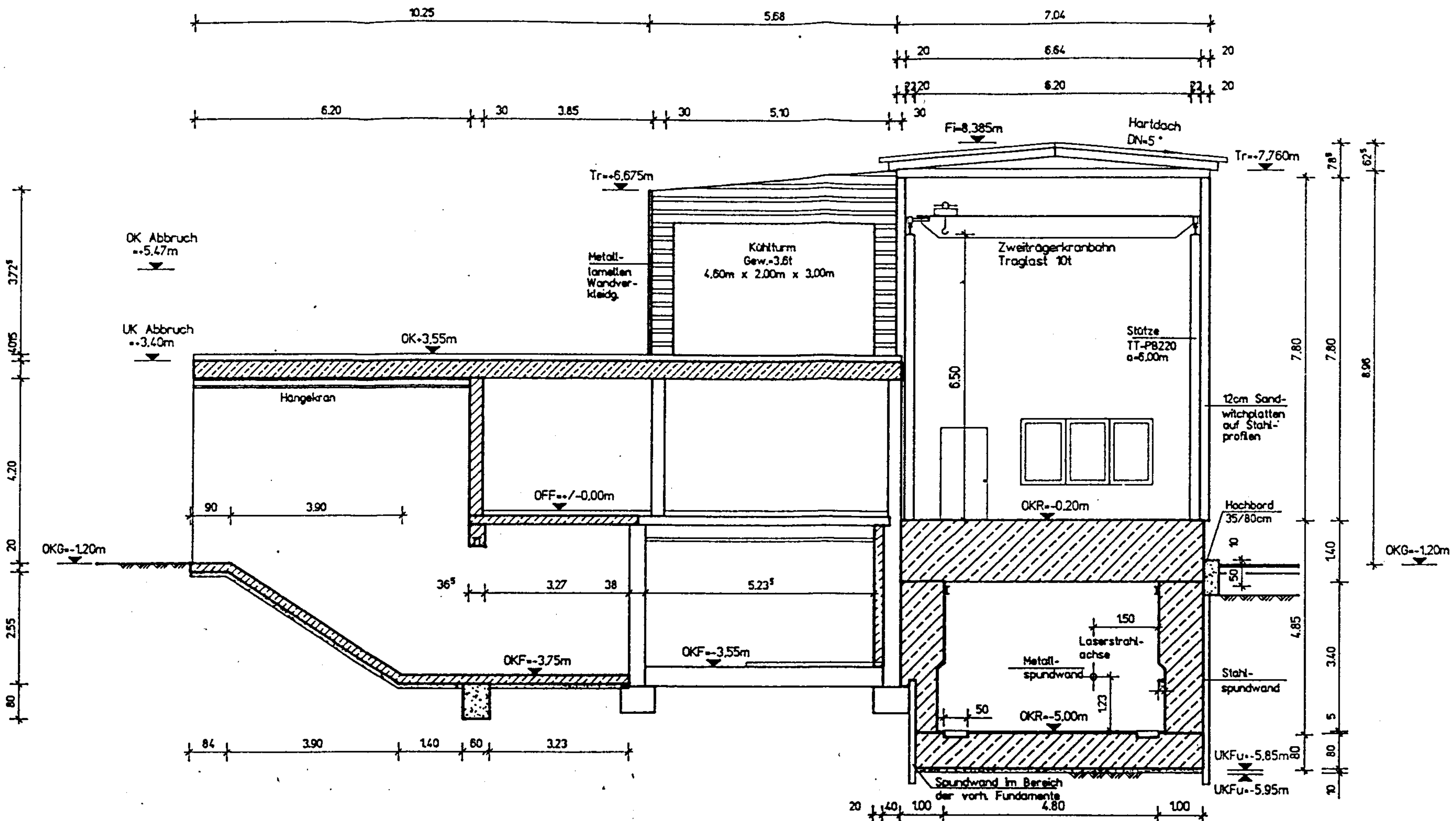
ACHTUNG
Sämtliche Maße sind am Bau zu prüfen !

LEGENDE

- Bestand MW
- Neubau Stahlbeton
- Neubau Abschirmwand
- Beton
- Kies
- Neubau KS-MW

IKW Ingenieurbüro - Bau Krüger/Weinert, Dipl.Ing.
Fasanenallee 6 15754 Bindow Tel. 033767/80116

GENEHMIGUNGSPLANUNG		SCHNITT A-A
Bauvorhaben: Klystron-Versuchshalle & Photo-Injektor Teststand DESY Platanenallee 6 15738 Zeuthen	Bauherr: Deutsches Elektronen Synchrotron DESY Platanenallee 6 15738 Zeuthen	Zeichnung Nr.: 04
		Maßstab: 1 : 100
		Datum: 29.11.1999
		Bauherr / Entwurfsverfasser



ACHTUNG

Sämtliche Maße sind am Bau zu prüfen !

LEGENDE

- Bestand MW
- Neubau Stahlbeton
- Neubau Abschirmwand
- Kies

IKW

Ingenieurbüro - Bau Krüger/Weinert, Dipl.Ing.
Fasanenallee 6 15754 Bindow Tel. 033767/80116

GENEHMIGUNGSPLANUNG

SCHNITT B-B

Bauvorhaben: Klystron-Versuchshalle & Photo-Injektor Teststand
DESY
Platanenallee 6
15738 Zeuthen

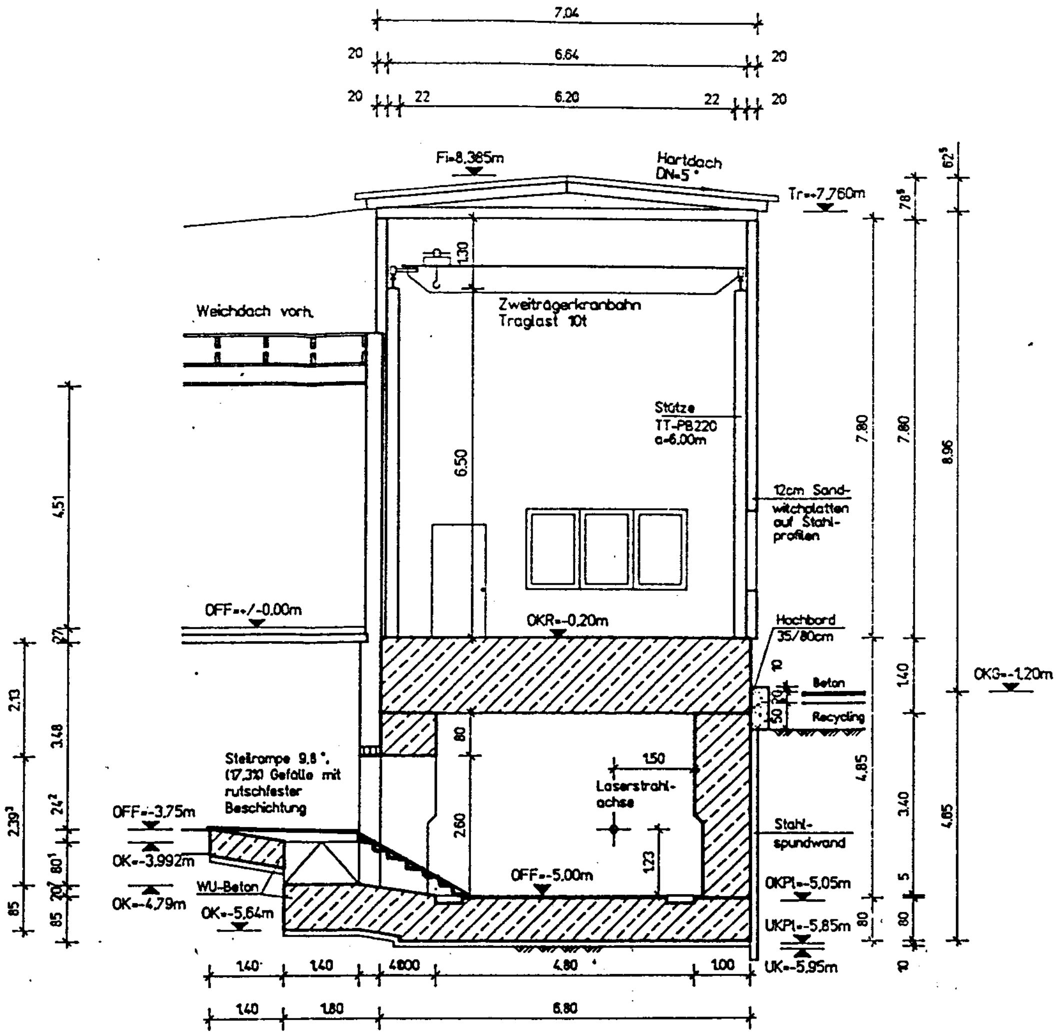
Bauherr: Deutsches Elektronen Synchrotron
DESY
Platanenallee 6
15738 Zeuthen

Zeichnung Nr.: 05

Maßstab: 1 : 100

Datum: 29.11.1999

Bauherr .... Entwurfsverfasser



ACHTUNG
Sämtliche Maße sind am Bau zu prüfen !

LEGENDE

- Bestand MW
- Abbruch
- Neubau Stahlbeton
- Neubau Abschirmwand
- Kies

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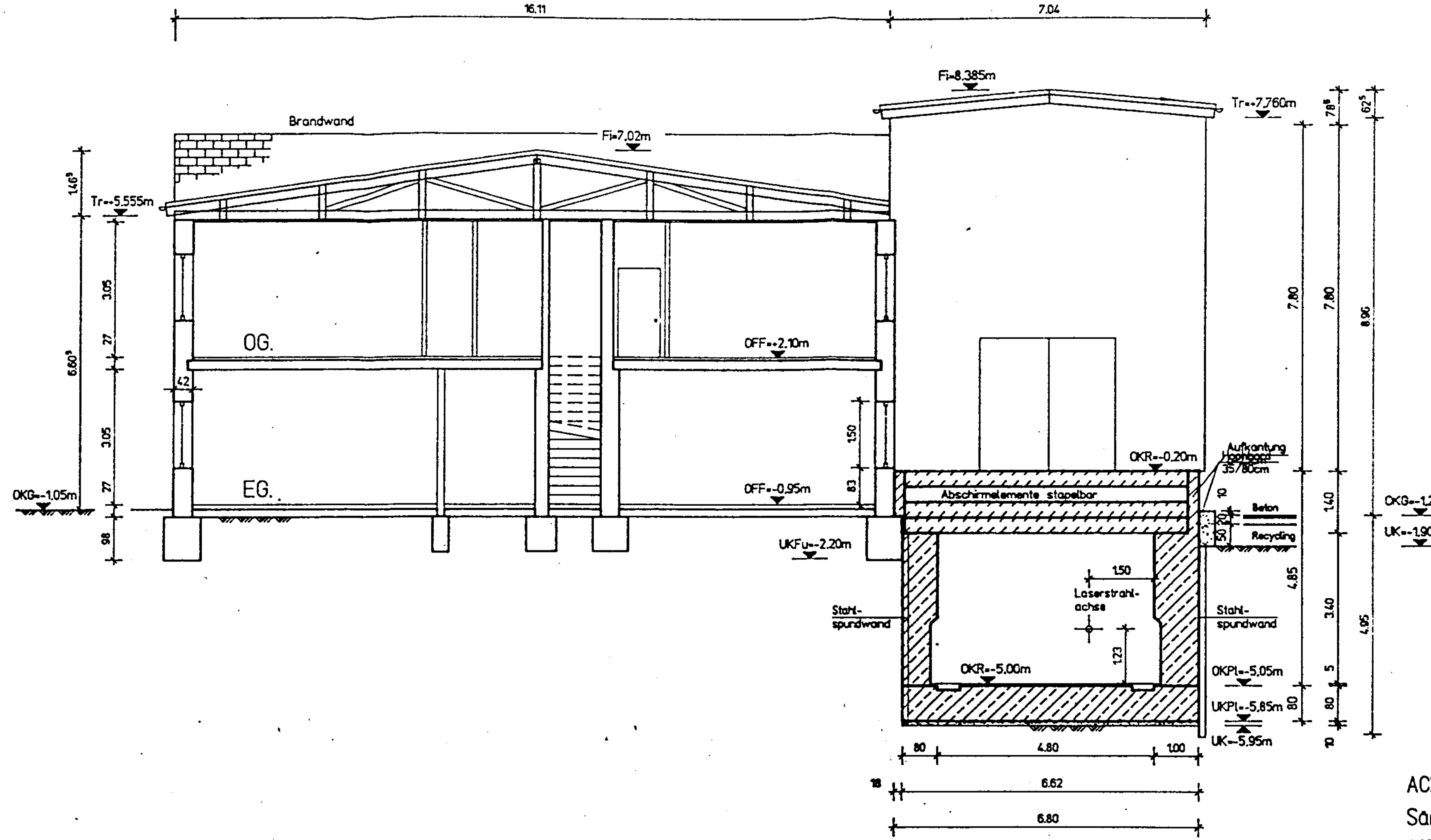
Fasanenallee 6 15754 Bircow Tel. 033767/80116

GENEHMIGUNGSPLANUNG — **SCHNITT C-C**

Bauvorhaben: Klystron-Versuchshalle & Photo-Injektor Teststand DESY Platanenallee 6 15738 Zeuthen	Bauherr: Deutsches Elektronen Synchrotron DESY Platanenallee 6 15738 Zeuthen	Zeichnung Nr.: 06
		Maßstab: 1 : 100
		Datum: 29.11.1999
		Bauherr: … Entwurfsverfasser: …



ACHTUNG

Sämtliche Maße sind am Bau zu prüfen !

LEGENDE

- Bestand MW
- Abbruch
- Neubau Stahlbeton/B25
- Neubau Abschirmwand
- Kies

IKW

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Fasanenallee 6 15754 Bindow Tel. 033767/80116

GENEHMIGUNGSPLANUNG

SCHNITT D-D

Bauvorhaben: Klystron-Versuchshalle & Photo-Injektor Teststand
DESY
Platanenallee 6
15738 Zeuthen

Bauherr: Deutsches Elektronen Synchrotron
DESY
Platanenallee 6
15738 Zeuthen

Zeichnung Nr.:	07
Maßstab:	1 : 100
Datum:	29.11.1999
Bauherr	Entwurfsverfasser