INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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H4.SMR/210 - 19

SPRING COLLEGE ON PLASMA PHYSICS

(25 May - 19 June 1987)

RECENT WORK ON LASER MATTER INTERACTION AT GARCHING

K. EIDMANN

Max Planck Institute
for Quantum Optics
Germany

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X-ray generation by laser

K. Eidmann MPQ Garching, Germany

solid target ⟵ laser

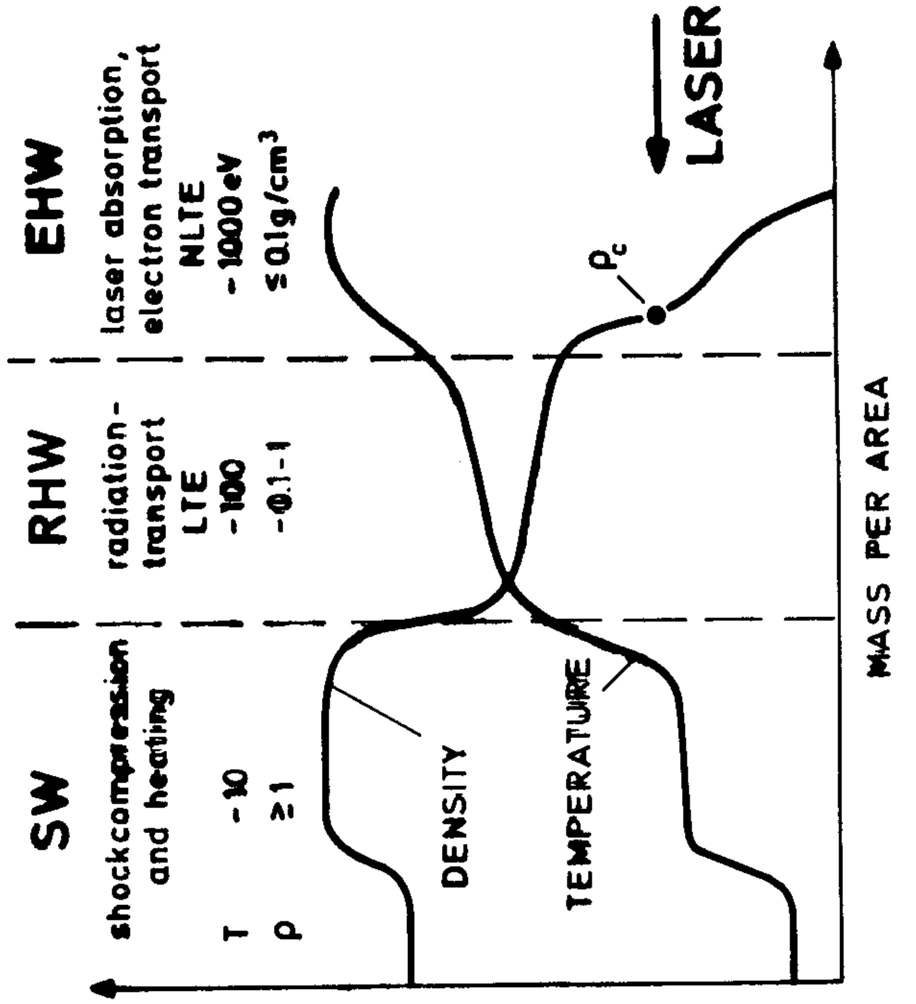
simple limiting case:

T, ρ = konst., optically thick

⟶ Planck radiation

T	$\sigma T^4 \left(= 10^5 T_{eV}^4 \frac{W}{cm^2}\right)$
50 eV	$6 \cdot 10^{11}$ W/cm²
100 "	$1 \cdot 10^{13}$ "
200 "	$1.6 \cdot 10^{14}$ "
500 "	$6.3 \cdot 10^{15}$ "

2



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applications

- inertial confinement

Laser

(homogeneous illumination)

- x-ray laser (photoionization, recombination)
- x-ray lithography
- radiometry
- diagnostics (x-ray back lighting)
-
-
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-

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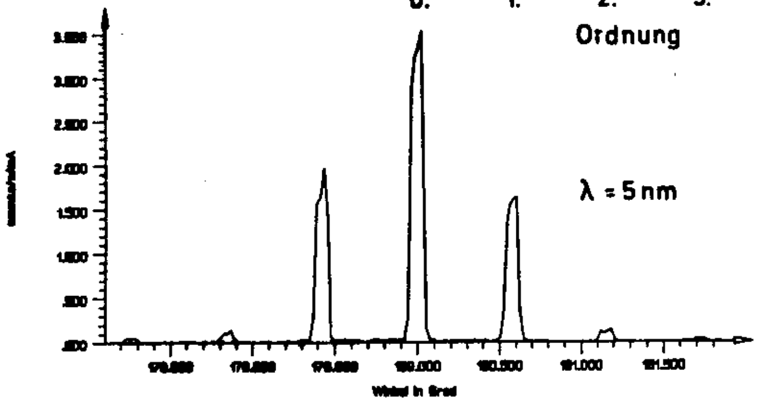
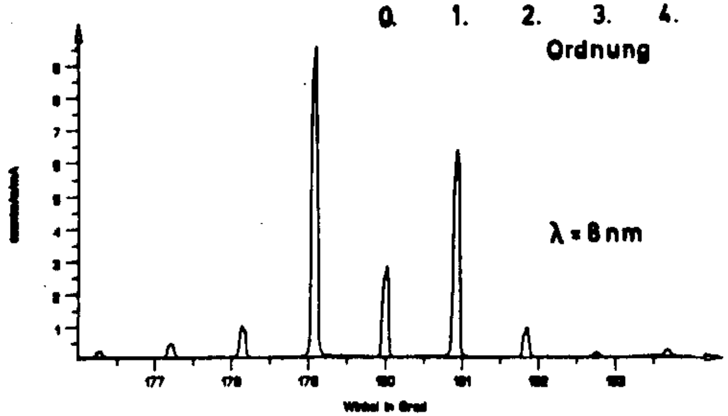
Transmissions-gitter (1000-2000 l/mm)

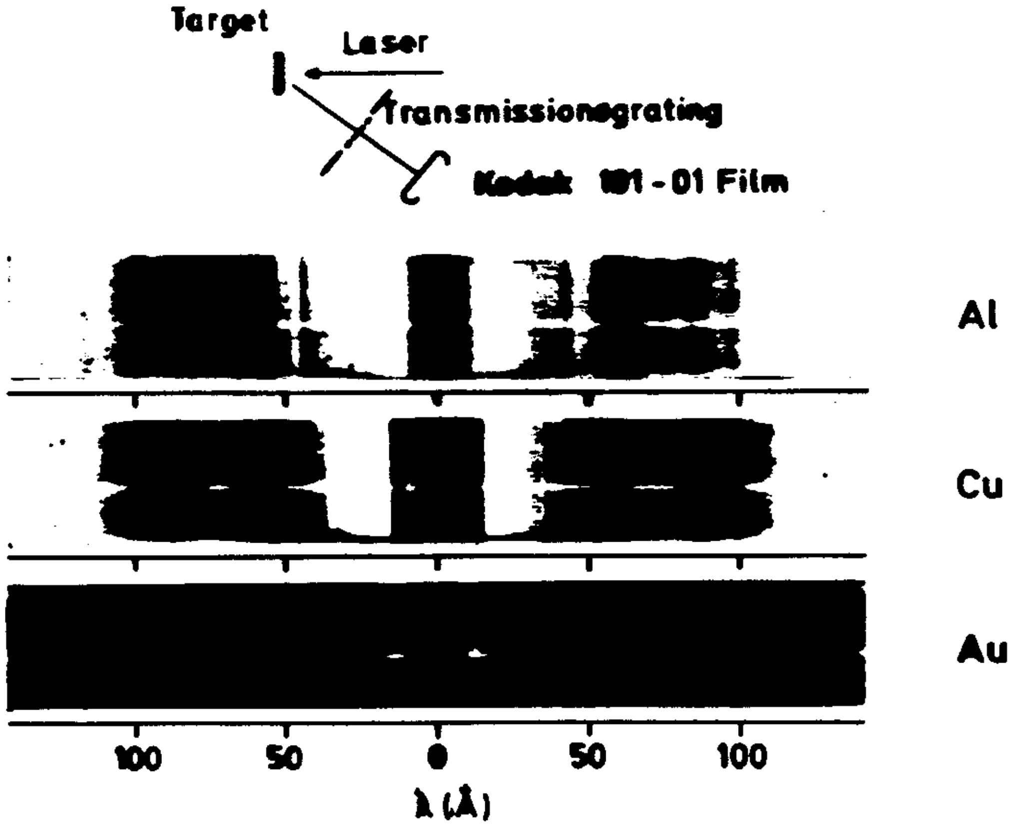
free standing gold wires as transmission grating

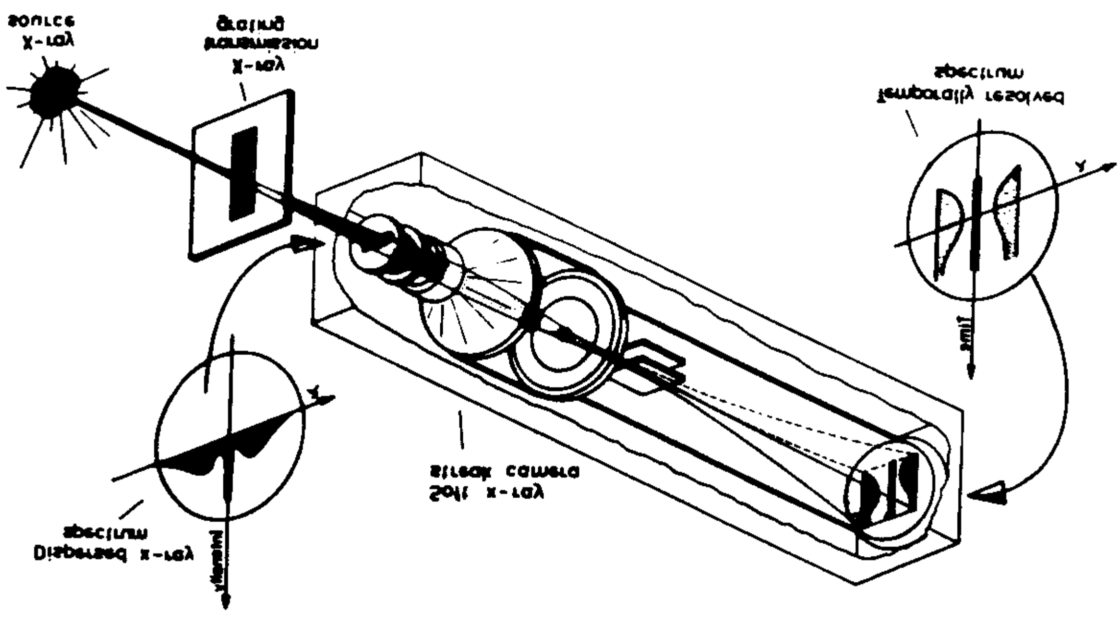
PTB (Bessy)

Gitter G4 2000 l/mm







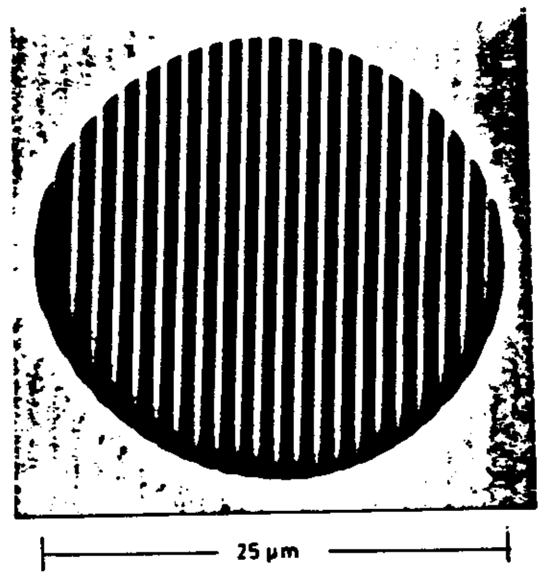


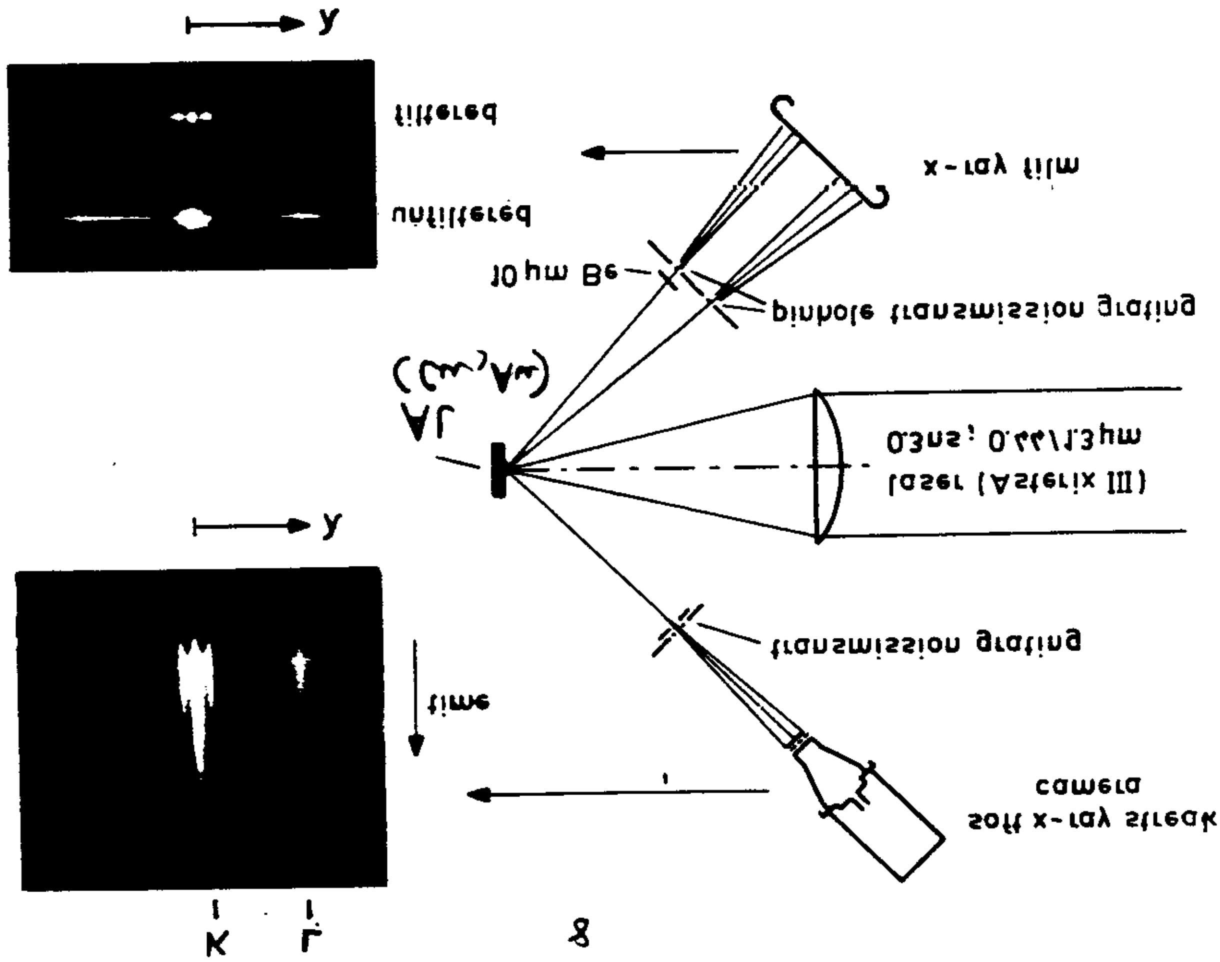
Time resolved soft x-ray spectrometer

959

7

Gitter # 130 333





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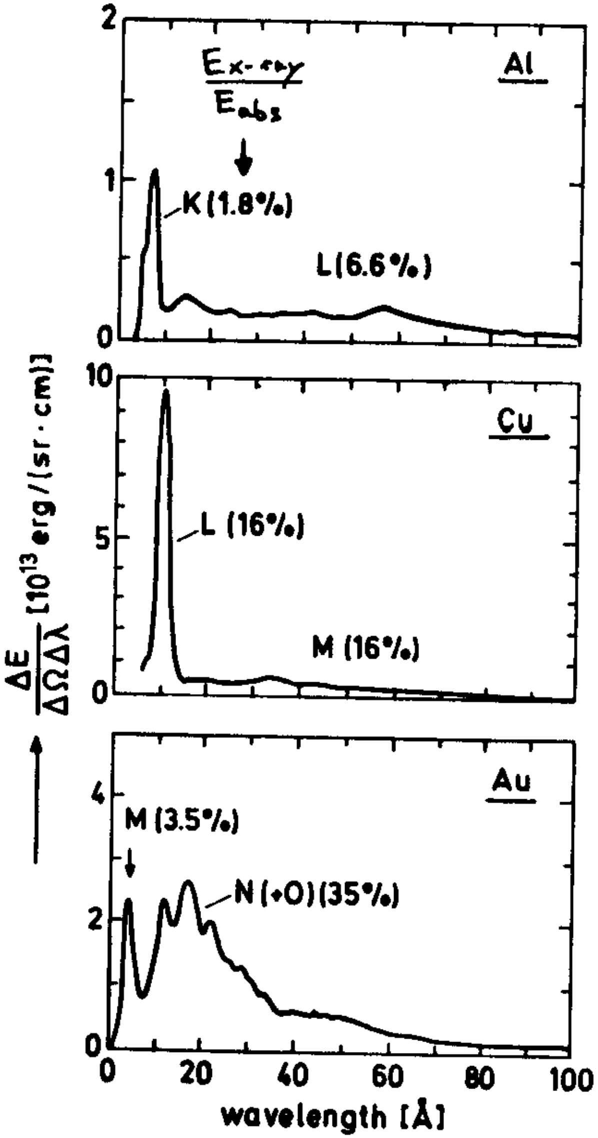
9



$\phi_{laser} \approx 10^{15} \frac{W}{cm^2}$

$\lambda = 0.44\,\mu m$

$\tau = 0.3\,ns$

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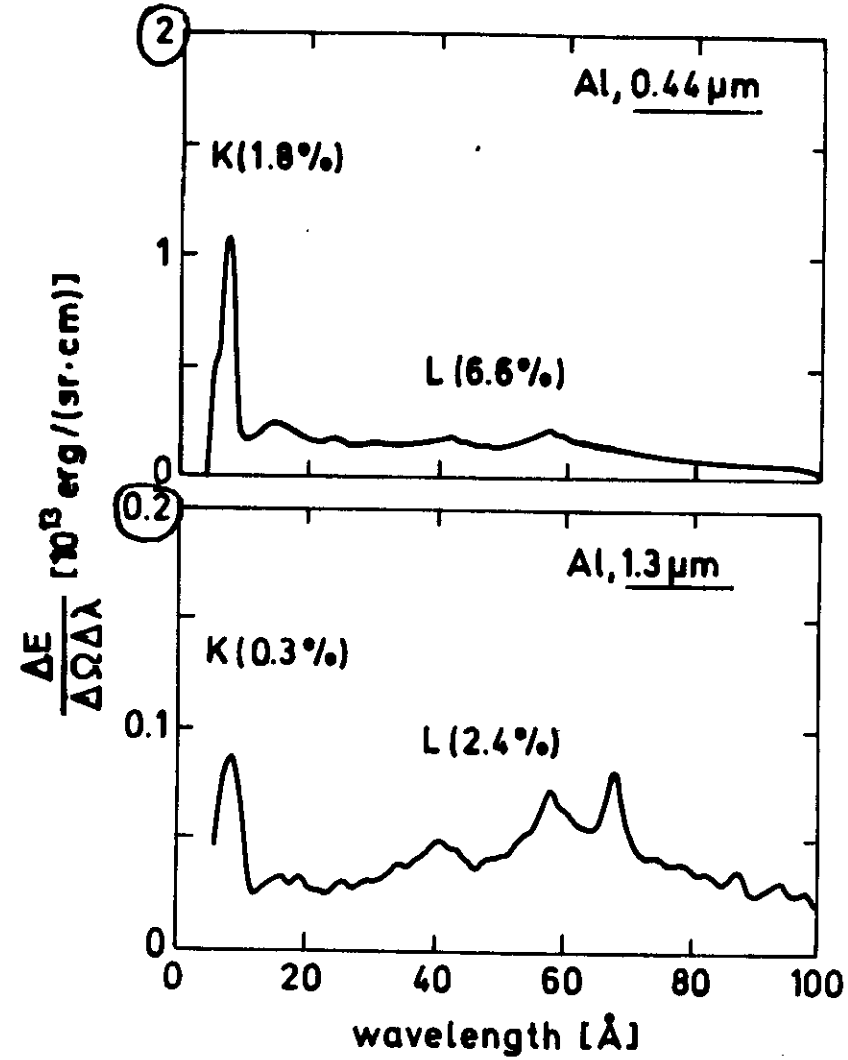
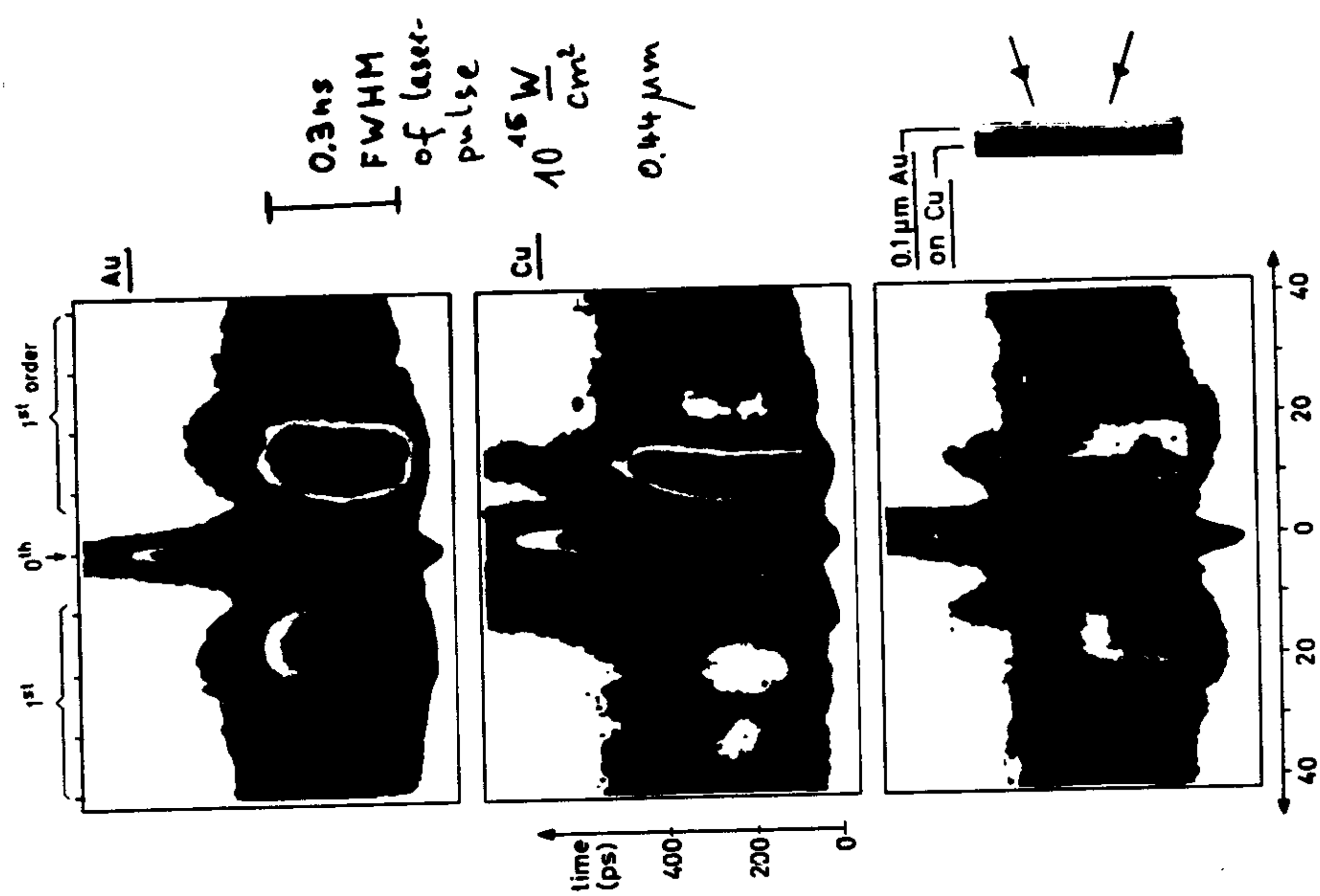
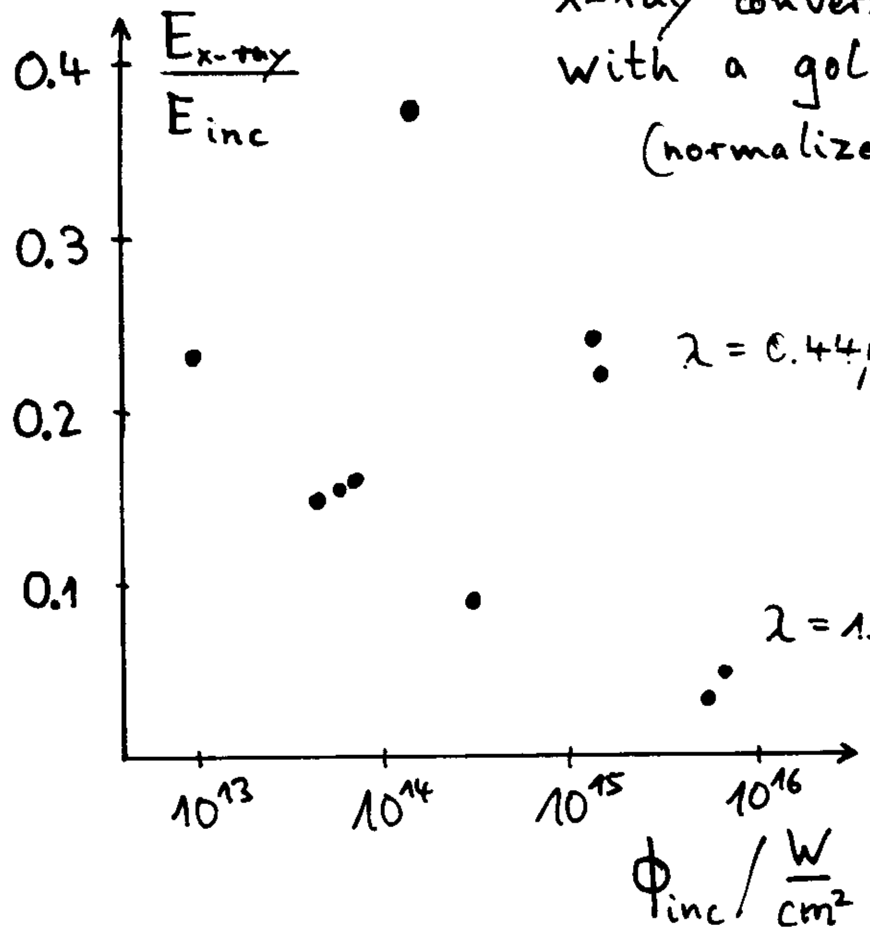


$10^{15} \frac{W}{cm^2}$

0.3 ns



X-ray conversion efficiency with a gold target (normalized to incident energy !)



Theoretical modelling

Hydrocode with
multigroup radiation transport

"MULTI"

Non-LTE emission (η) and absorption (κ) coefficients are calculated by "SNOP"
(Stationary Non LTE opacities)

"SNOP" calculates for given ρ and T steady state values $\eta(h\nu)$, $\kappa(h\nu)$.

"MULTI"

mass
$$\frac{\partial \rho}{\partial t} = -\rho^2 \frac{\partial v}{\partial m}$$

momentum
$$\frac{\partial v}{\partial t} = -\frac{\partial p}{\partial m}$$

energy
$$\frac{\partial e}{\partial t} = -p\frac{\partial v}{\partial m} - \frac{\partial q}{\partial m} - \sum_k \frac{\partial S_k}{\partial m} + \frac{Q}{\rho}$$

radiation transport
$$\frac{\partial S_k}{\partial m} = c\kappa_P^k(\varepsilon_k U_P^k - U_k)$$

"SNOP"

$$c g_k^2 \frac{\partial U_k}{\partial m} = -\kappa_R^k S_k$$

$$\boxed{\begin{aligned}\eta &= \eta^{ff} + \eta^{fb} + \eta^{bb}\\ \kappa &= \kappa^{ff} + \kappa^{bf} + \kappa^{bb}\end{aligned}}$$

- ionization state:

  electron collisional ionization =

  collisional + radiative recombination

  (Saha, Corona are limiting cases)

- η^{bb}:

  high density: Boltzmann

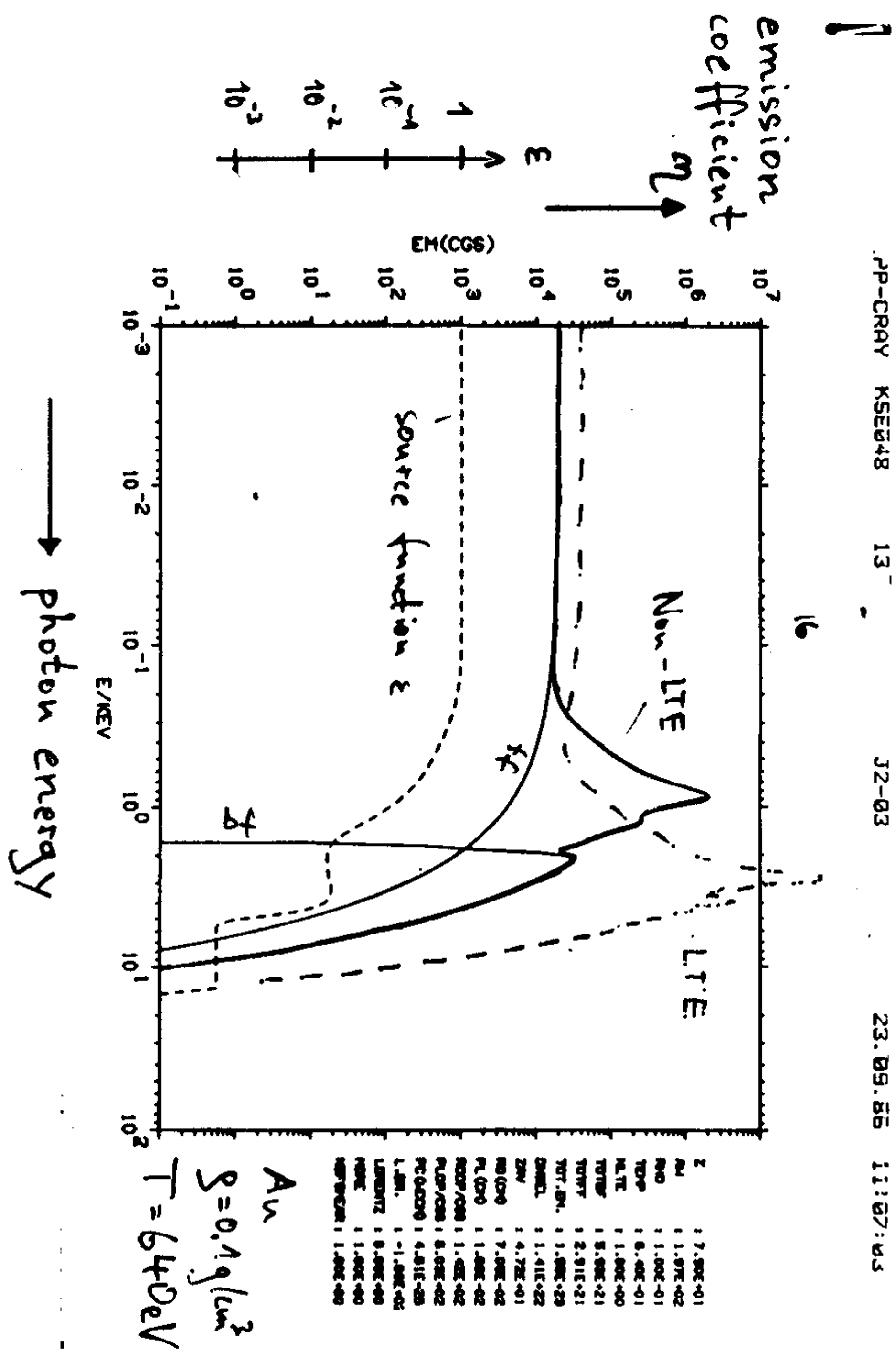
  $$\eta^{bb}_B \propto \rho$$

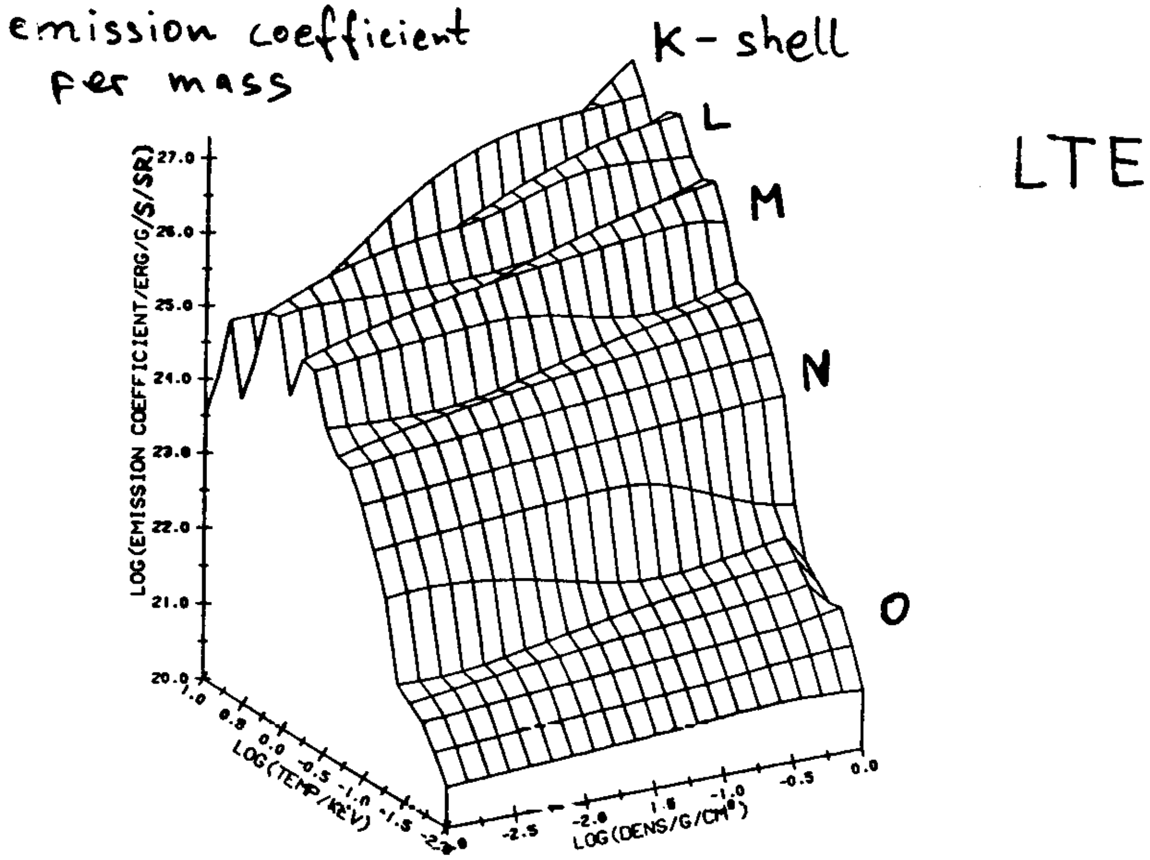
  low density: Corona

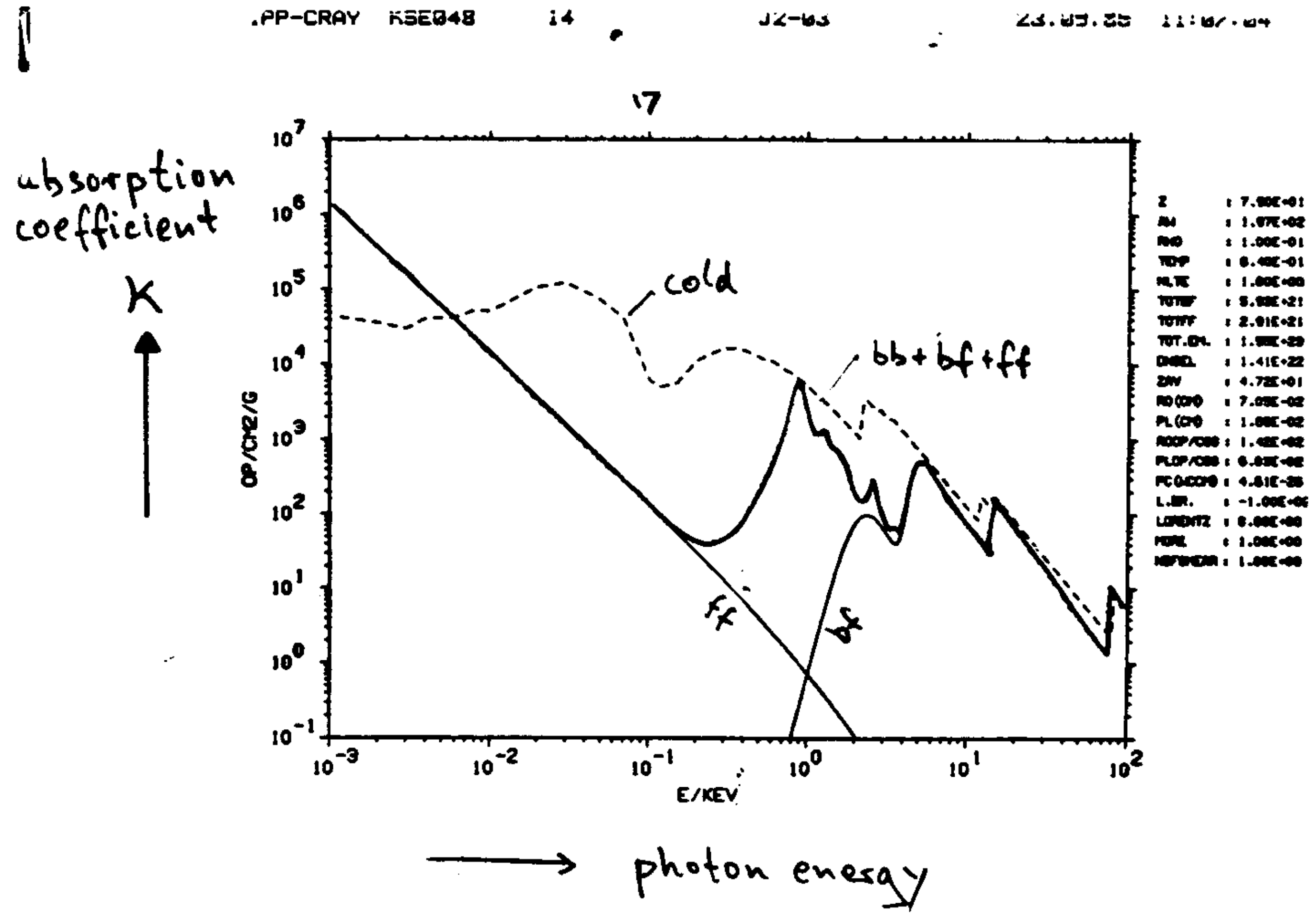
  $$\eta^{bb}_c \propto \rho^2$$

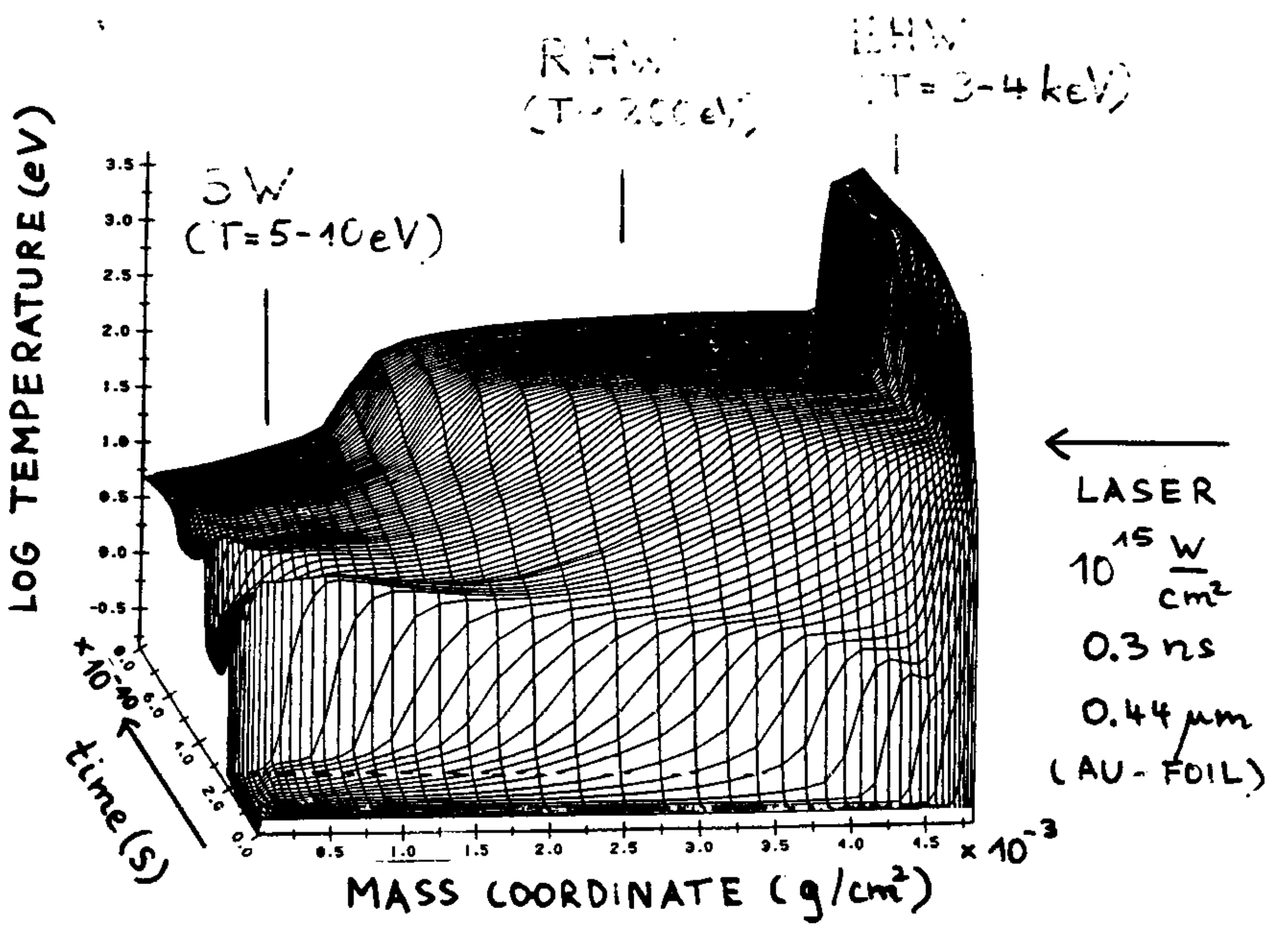
  in between: $\dfrac{1}{\eta} = \dfrac{1}{\eta^{bb}_B} + \dfrac{1}{\eta^{bb}_c}$

- hydrogenlike energy levels




emission coefficient
per mass
K-shell
L
M
N
O
LTE
LOG(EMISSION COEFFICIENT/ERG/G/S/SR)
LOG(TEMP/KEV)
LOG(DENS/G/CM³)


.PP-CRAY K5E048 14 J2-63 23.05.85 11:07.04
17
absorption
coefficient
K
OP/CM2/G
E/KEV
cold
bb+bf+ff
ff
bf
photon energy



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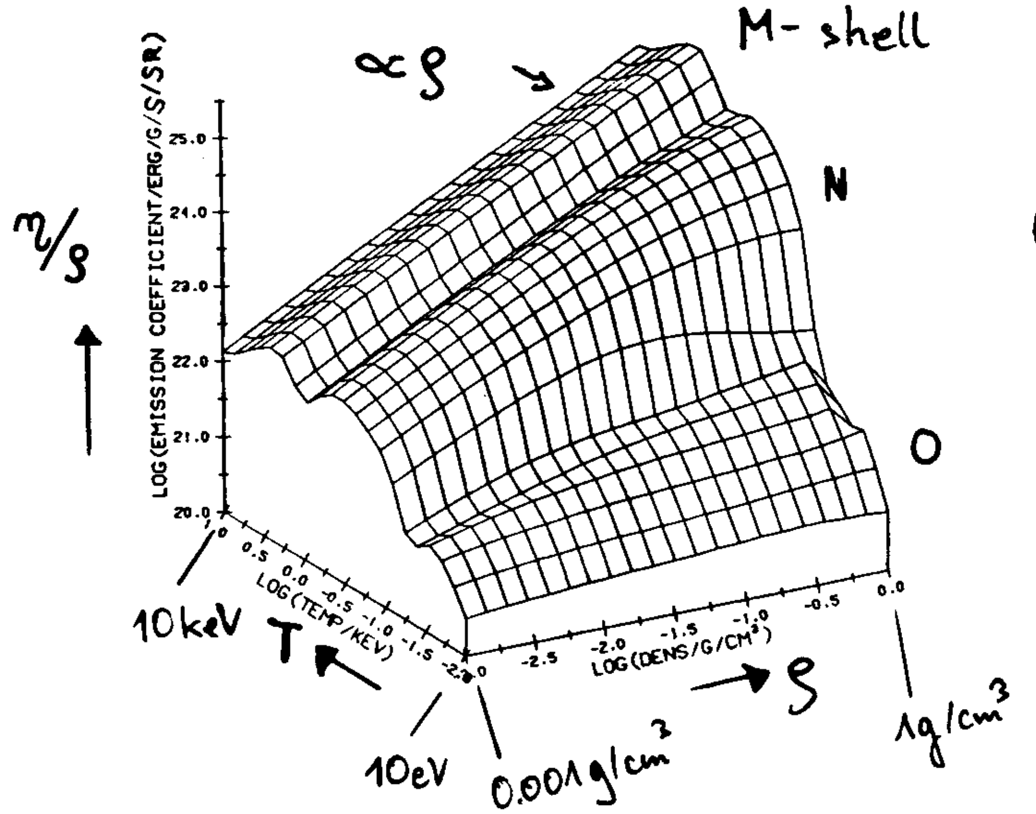
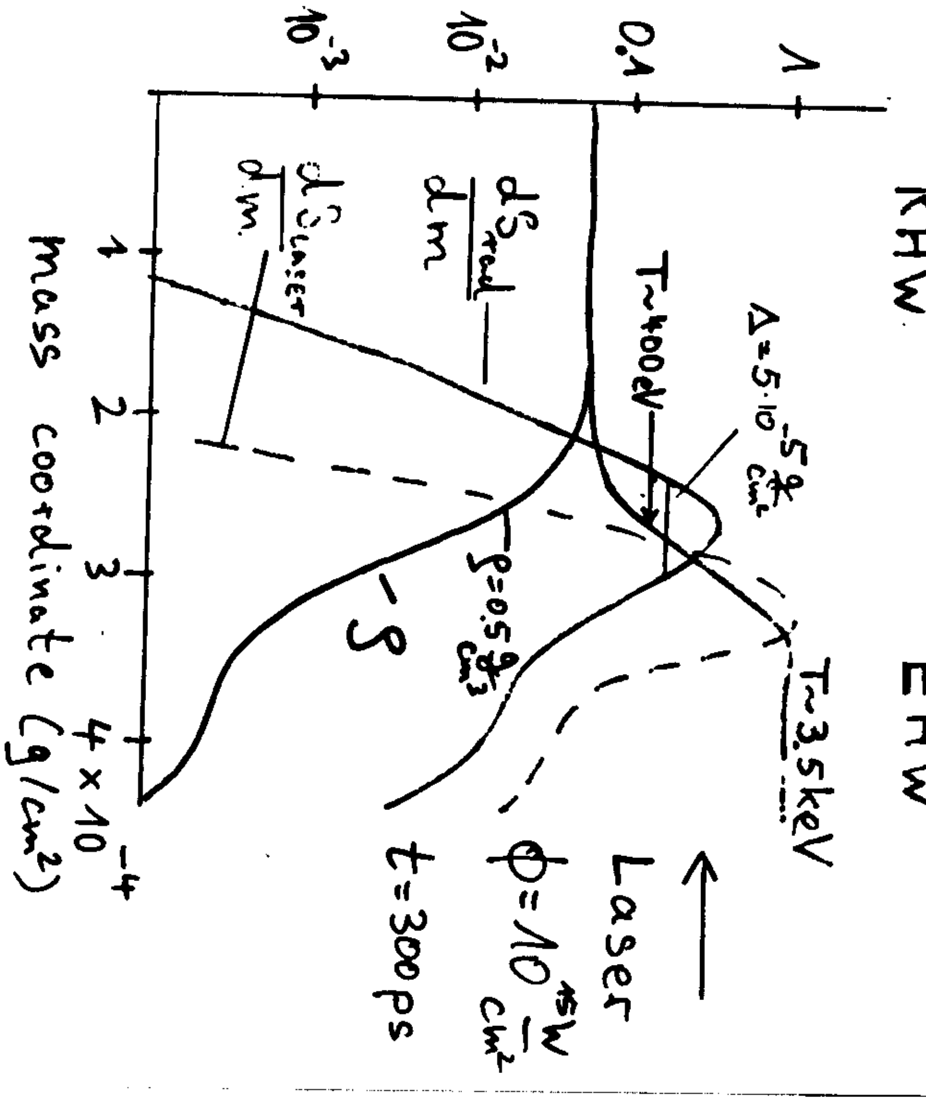
frequency integrated emission coefficient per mass

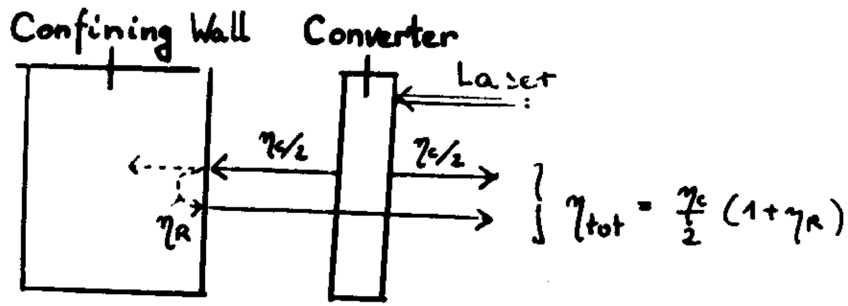


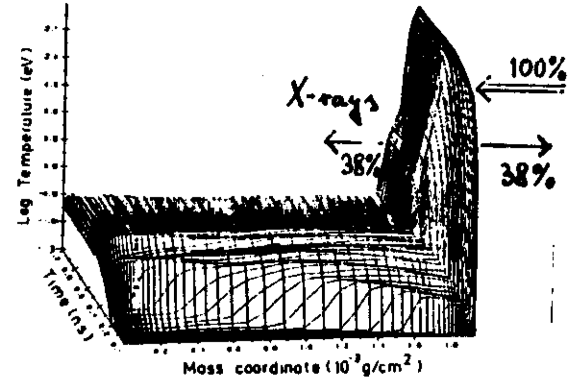
NLTE
(SNOP)

X-ray energy $\sim \eta_{\rho}(T,\rho)\cdot\Delta$



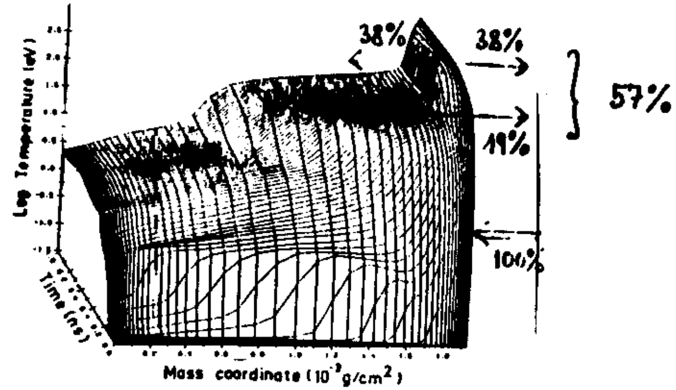
Total Conversion = Direct Conversion + "Reemission"





Radiation Absorption artificially suppressed:

$$\frac{dI_\nu}{dx} = \eta_\nu - \cancel{\kappa_\nu I_\nu}$$



Reference Case: $\phi = 10^{14}\ \frac{W}{cm^2}$, $\lambda = 0.44\ \mu m$, $\tau = 300\ ps$, $f = 0.08$, Au

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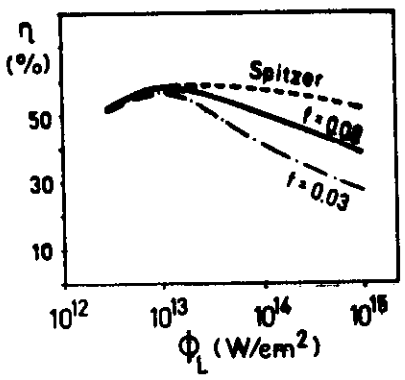
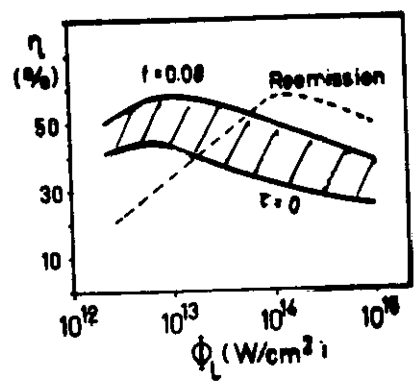
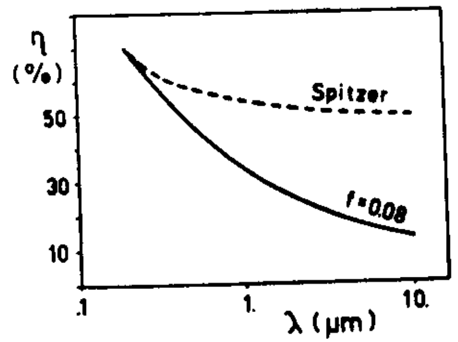
flux limit



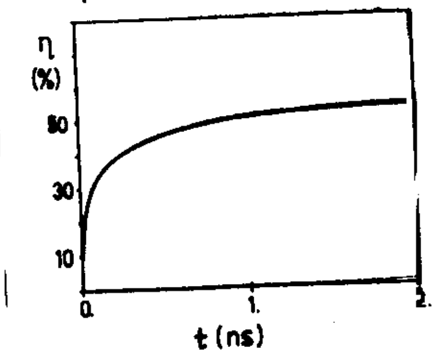
wall reemission



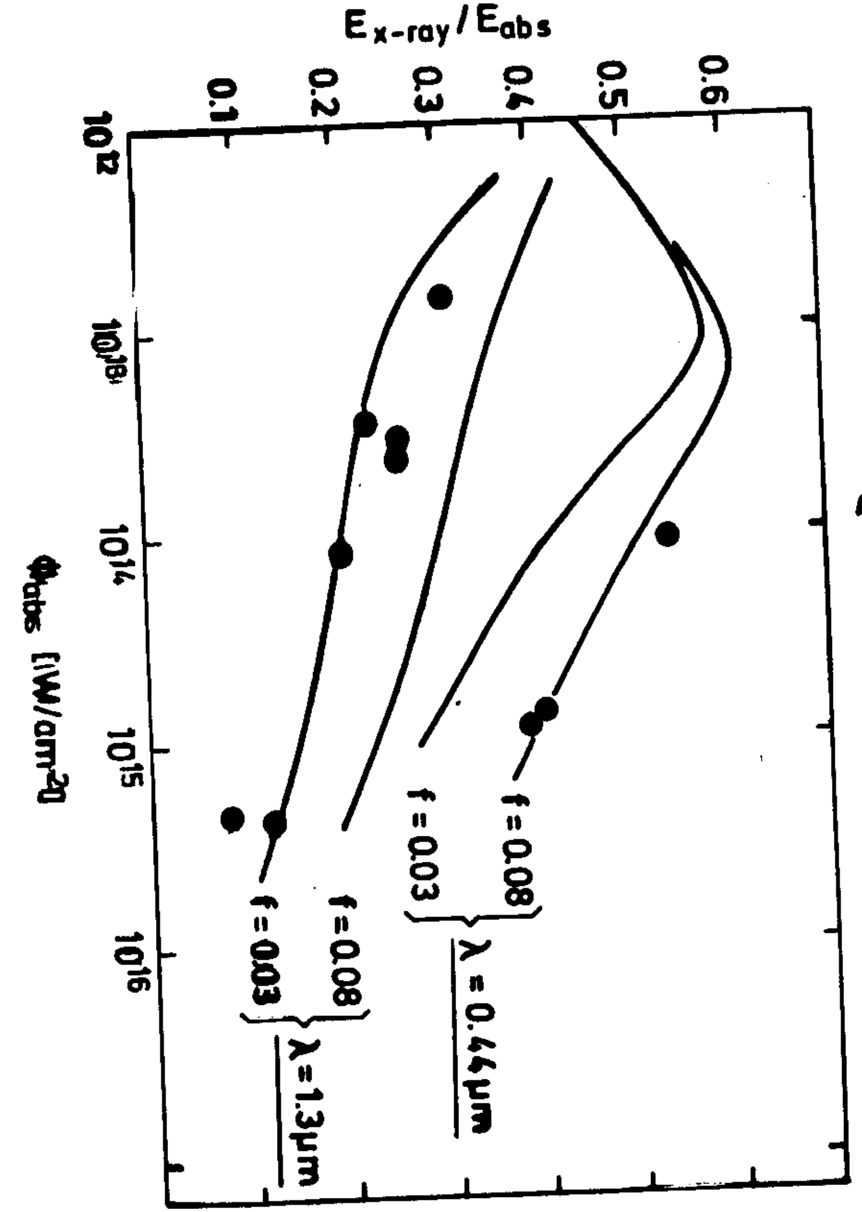
wavelength λ



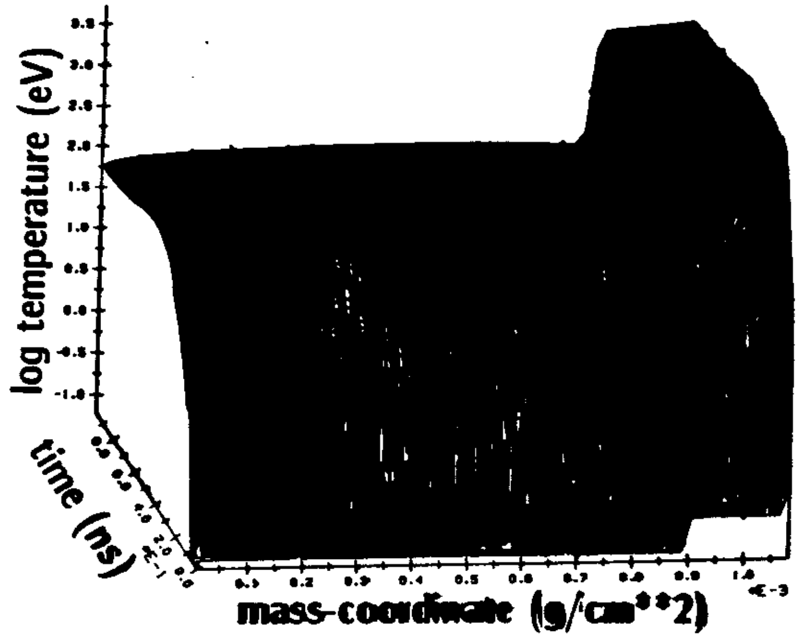
pulse time τ



X-ray conversion efficiency of gold

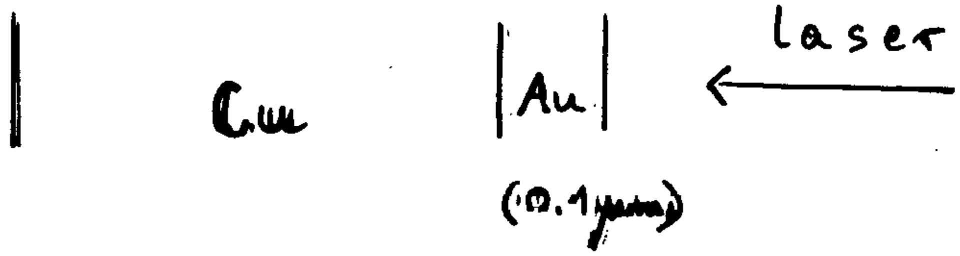


Conversion Parameters

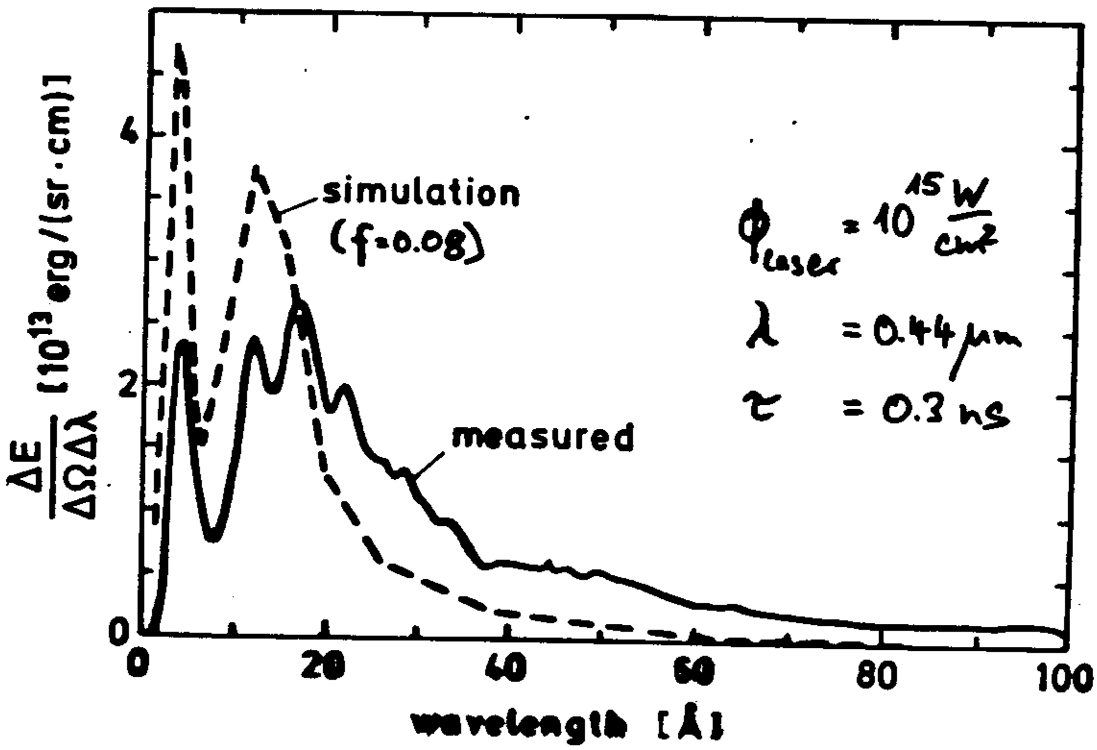


$10^{15} \frac{W}{cm^2}$

0.3 ns, 0.44 μm



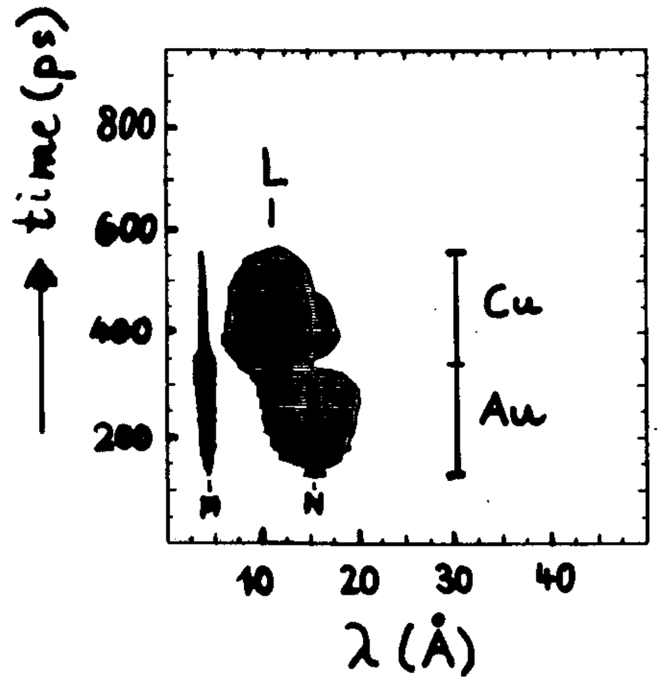
gold spectrum 25



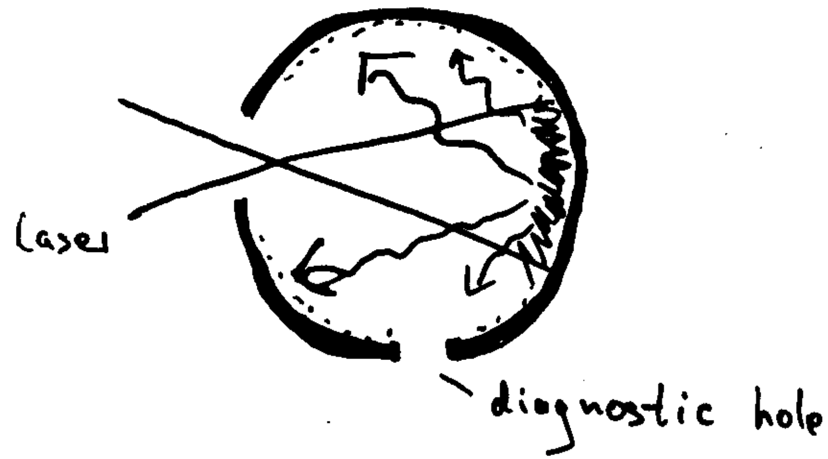
$\phi_{laser} = 10^{15} \frac{W}{cm^2}$

$\lambda = 0.44 \mu m$

$\tau = 0.3$ ns



study of empty gold cavities

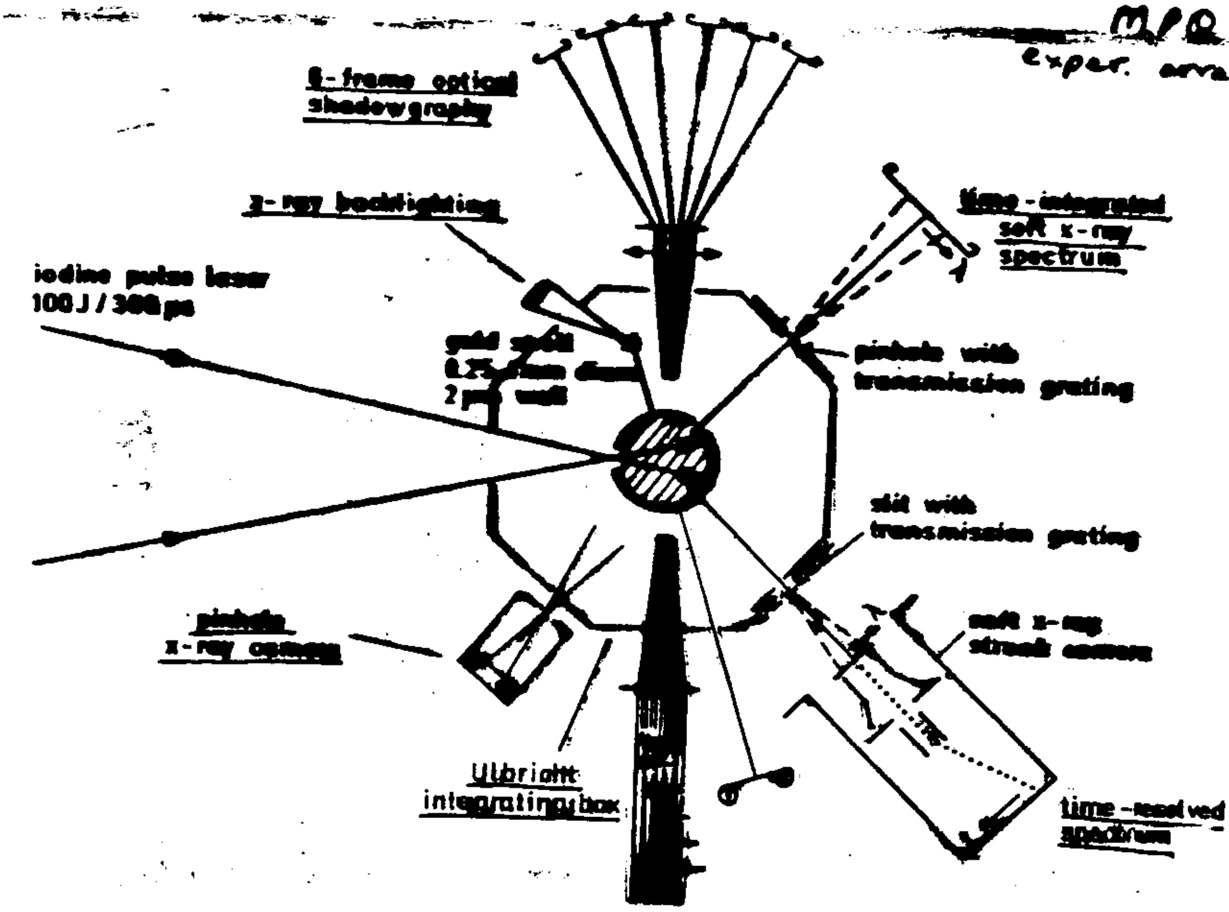


→ Planck radiation (radiometry)

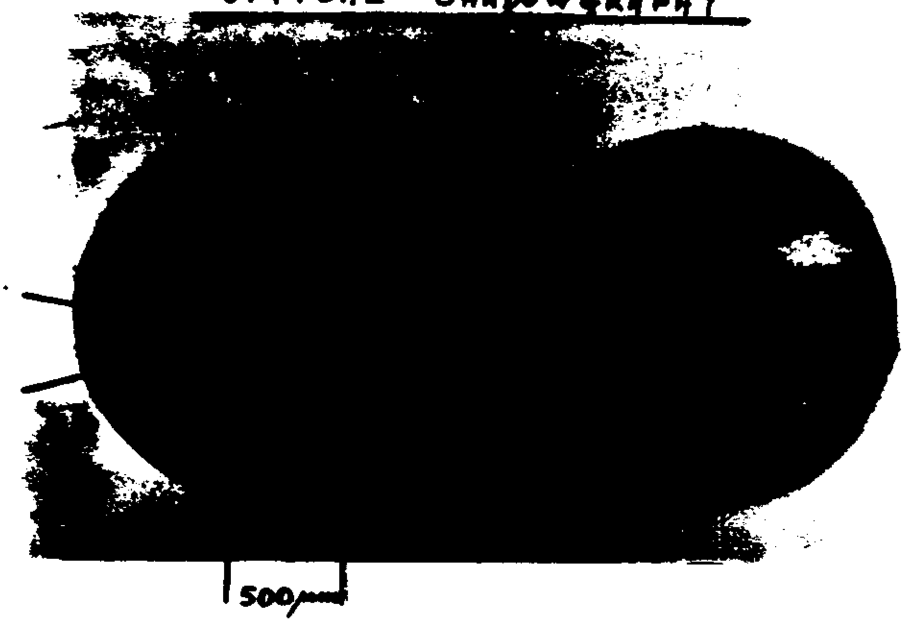
→ uniform illumination of pellets

(intensity enhancement possible ?)

M/Q
exper. arrangemen

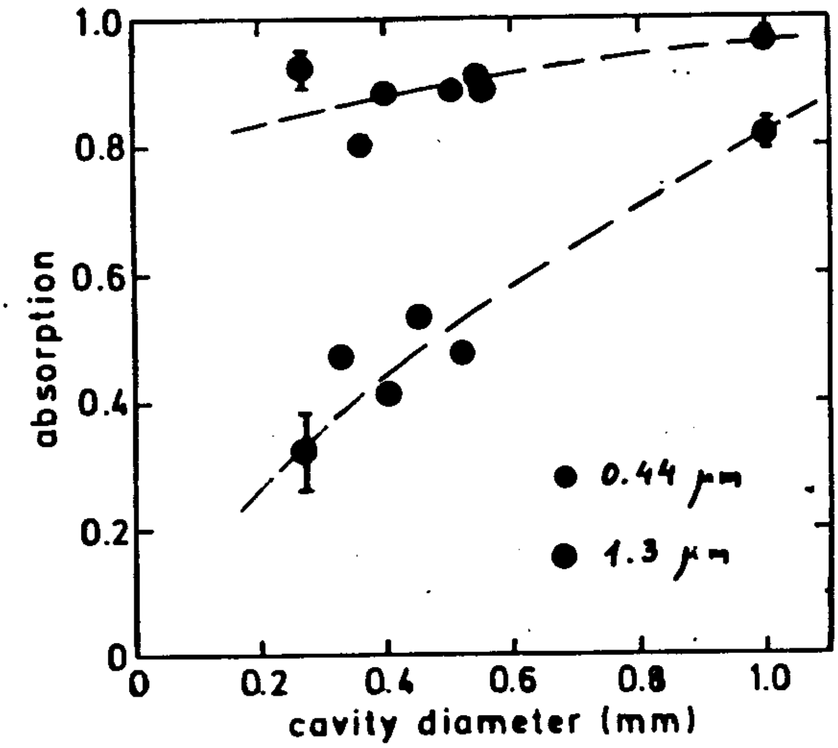


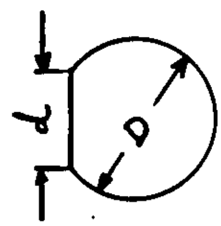
Optical Shadowgraphy



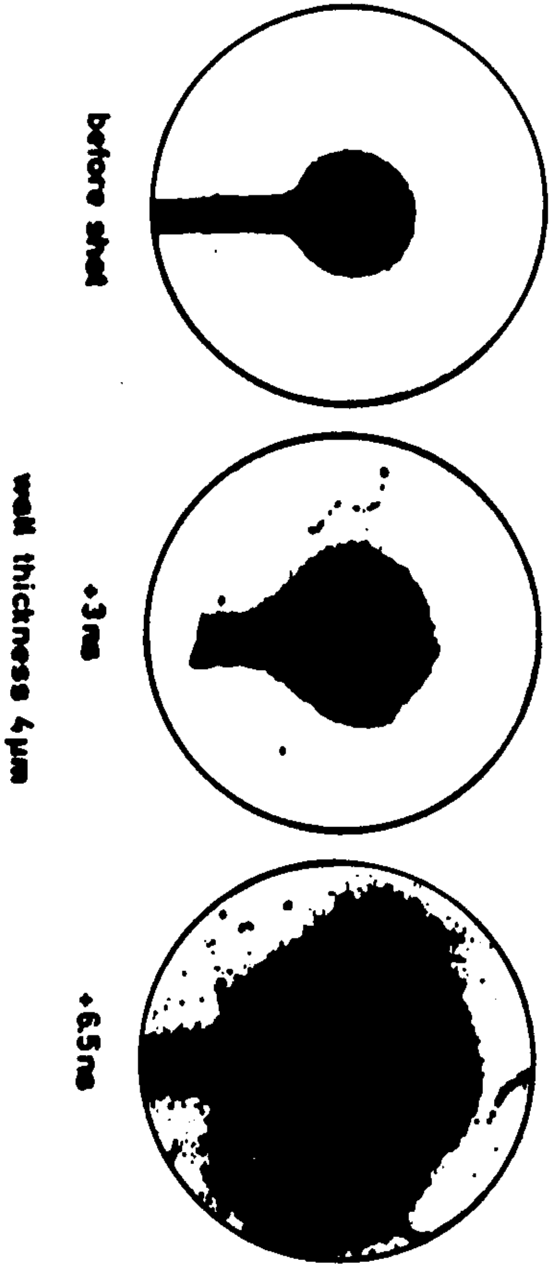
LEITZ 4734 T. 4K:K:S

Cavity Absorption Measurements





$d \simeq 0.6\,D$



X-RAY BACKLIGHTING

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$v \sim 6 \cdot 10^6 \frac{cm}{s}$

PINHOLE TRANSMISSION GRATING RECORD

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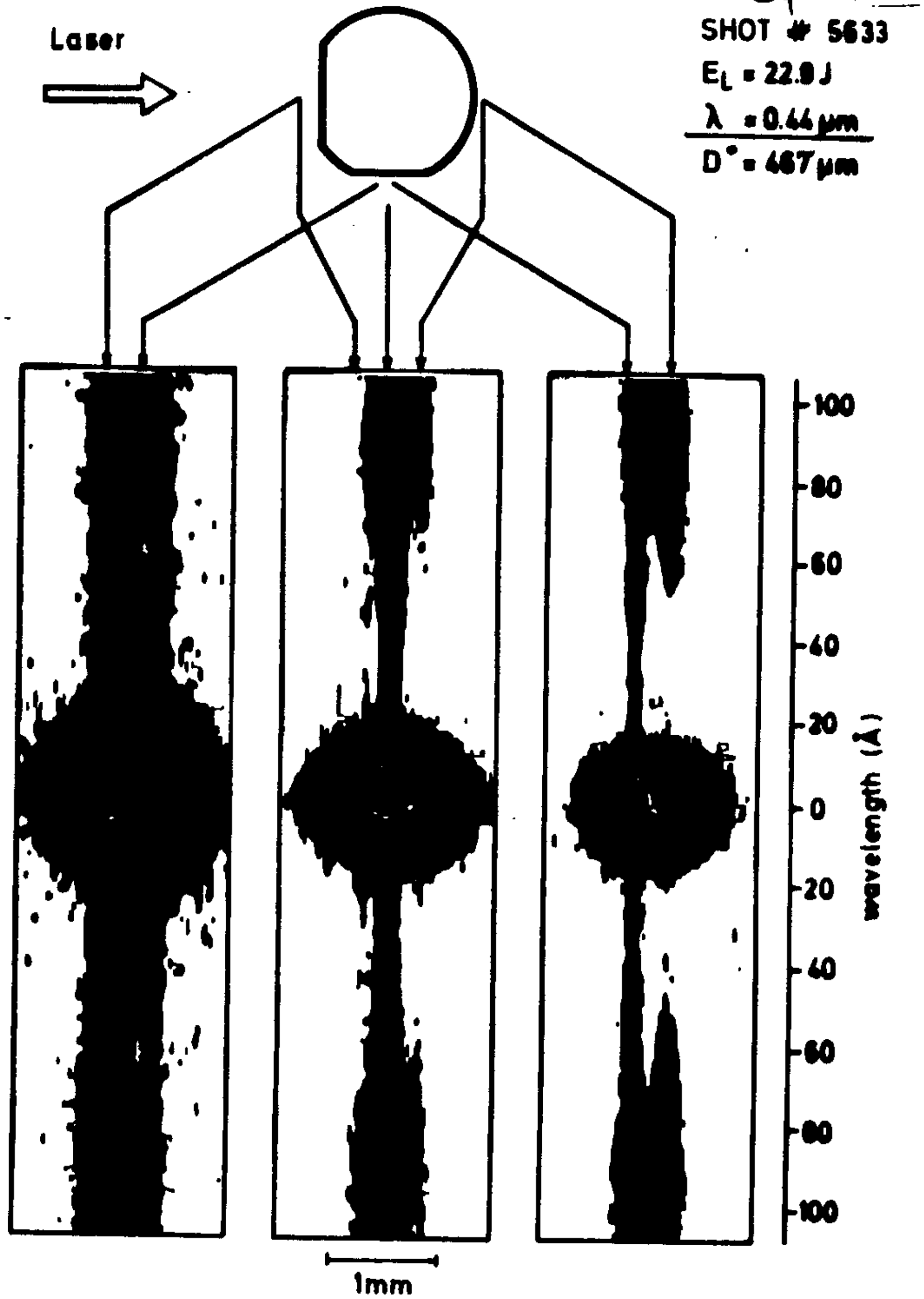

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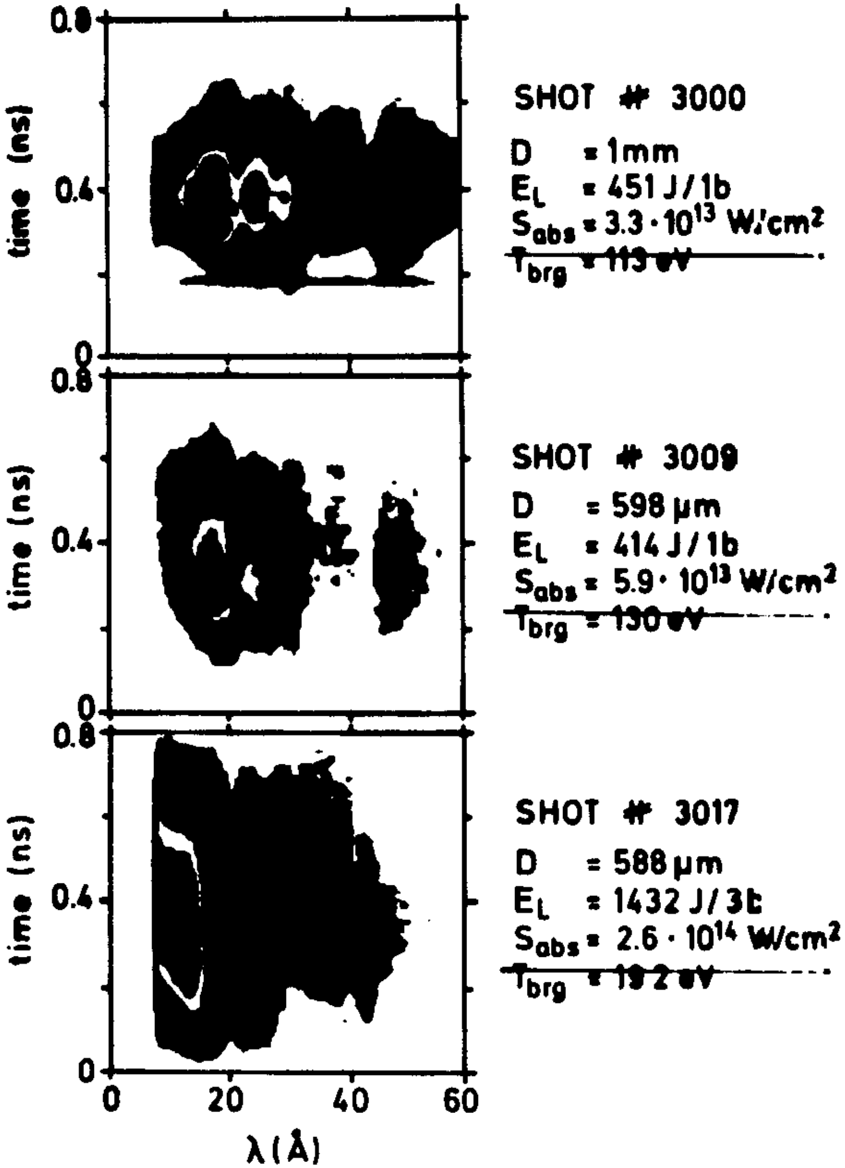

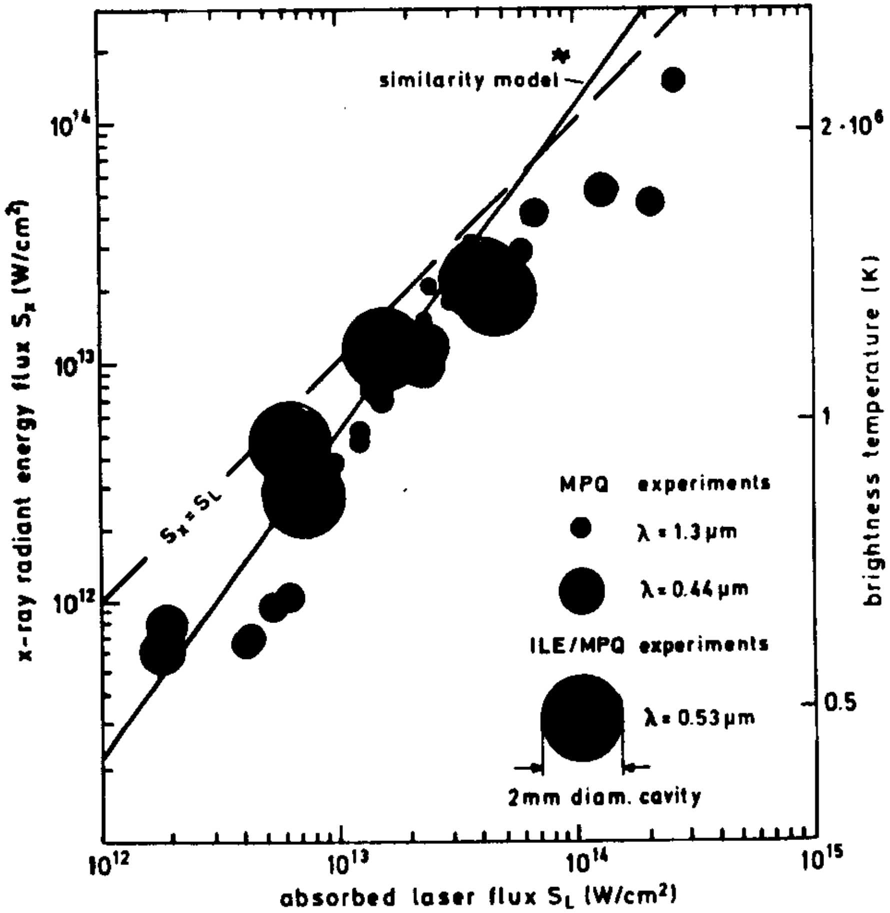

* Pakula, Sigel, Tsakiris : $S_x \propto S_L^{16/13}$

$(\kappa_\nu \propto \rho^0 / T^4)$