



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



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SMR/115 - 56

WINTER COLLEGE ON LASERS, ATOMIC AND MOLECULAR PHYSICS

(21 January - 22 March 1985)

DOPPLER-FREE TWO-PHOTON SPECTROSCOPY

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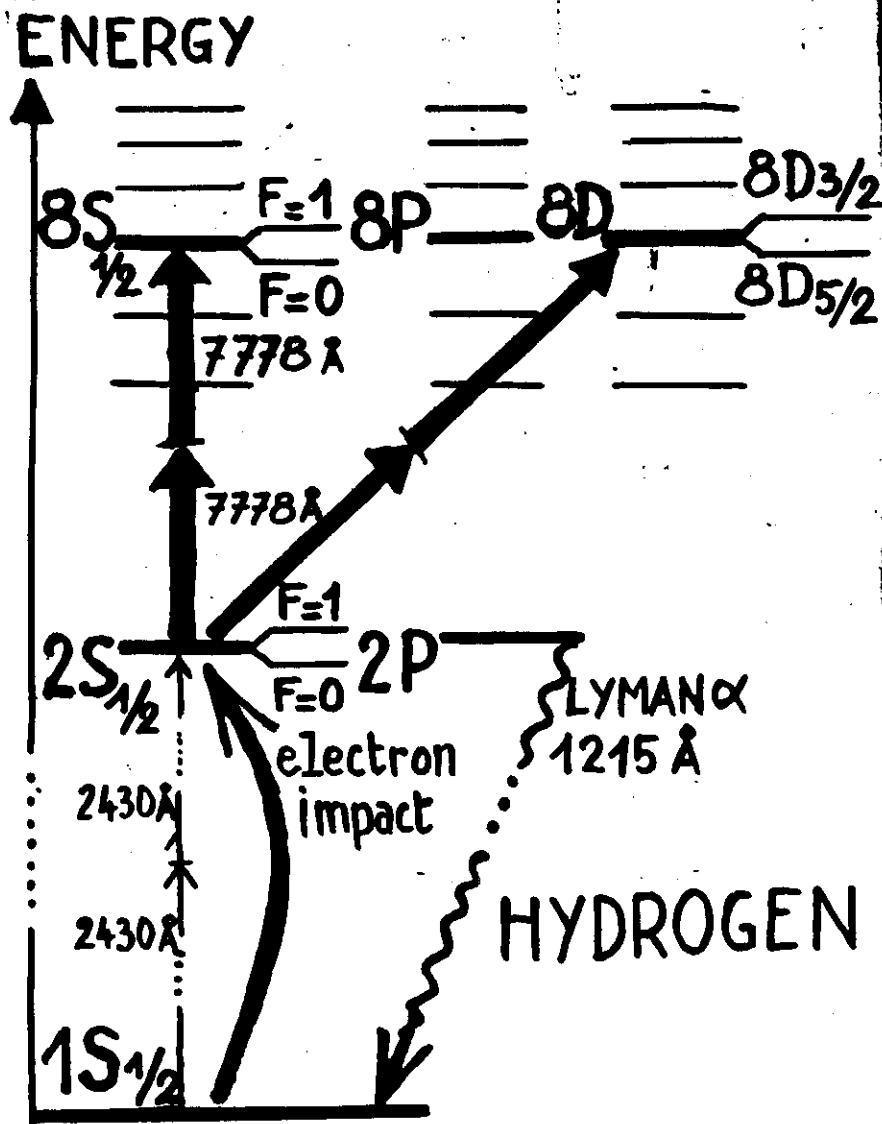
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Missing or extra copies are available from Room 229.

# DOPPLER-FREE 2-PHOTONS

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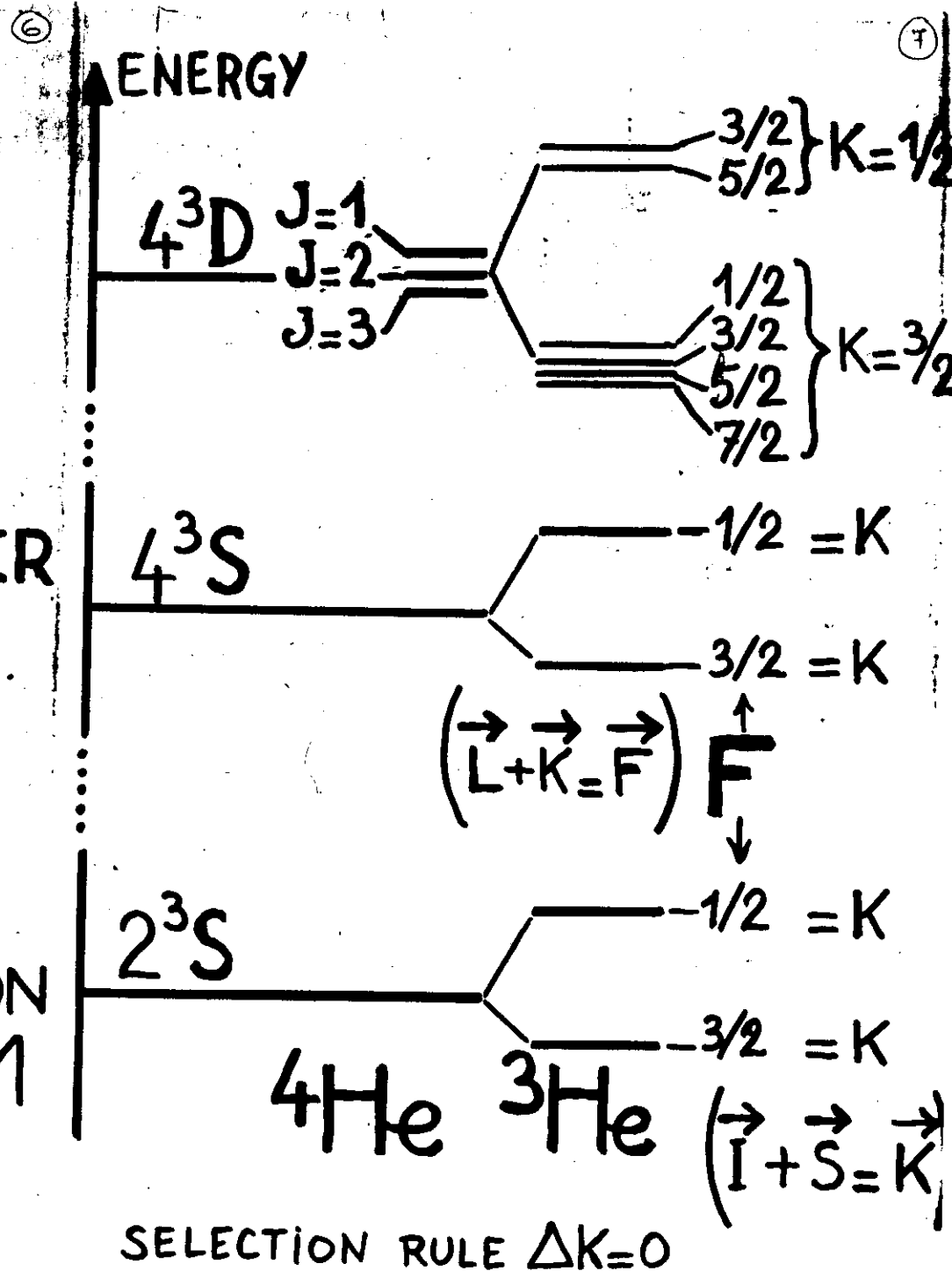
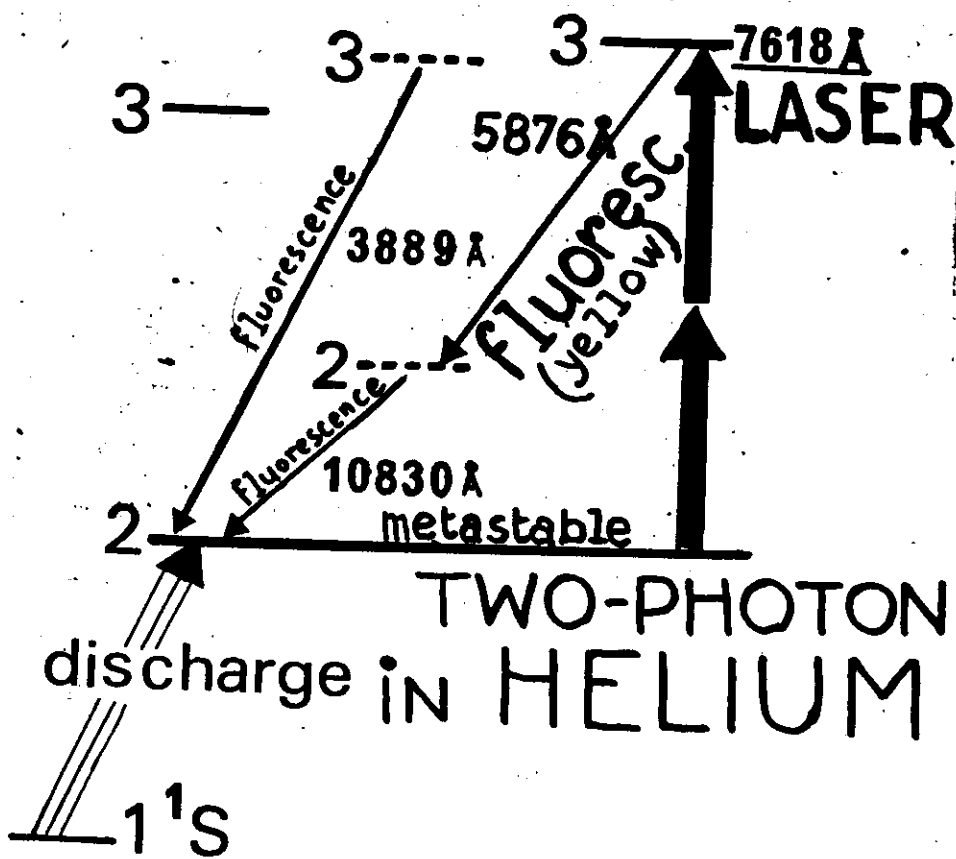
Cambridge (Harvard) Los Angeles	BLOEMBERGEN SALOUR LEVENSON HARPER	F.S.	Na Ne K	5 to 8 8 to 19
Toronto	STOICHEFF HARVEY KATO WEINBERGER	F.S. COLL. ISO	Rb	10 to 12
Stanford	HÄNSCH WIEMAN LEE WALLENSTEIN	ISO H.F.S.	H	2
New York (Columbia)	HARTMANN FLUSSBERG MOSSBERG	ISO H.F.S.	Te	7
Seattle	FORTSON ROBERTS	ISO H.F.S.	Rb	6
Kiel	NIEMAX WEBER PENDRILL LORENZEN	F.S., COLL. ISO ISO	Cs Ca Sr	18 to 23 9 to 85
Bonn	MEISEL JITSCHIN BURGHARDT DUBKE	F.S., H.F.S. F.S.	Na Ba	4
Berlin (Freie Univ.)	MATTHIAS TIMMERMAN BEIGANG LOCKE NEUKAMMER RINNEBERG	ISO H.F.S., ISO H.F.S. H.F.S., ISO	Pb Sr Ca Ba	7, 8 9 to 50 6 to 42 10 to 4
Mainz	HUBER ULM DENGAS KÖHL	F.S., ISO	In	~30

SATURATION	TWO-PHOTON	TWO-PHOTON APPLICATIONS
VELOCITY CLASS $v_z = 0$	OPPOSITE SHIFTS CANCEL OUT	ATOMIC SPECTRO { FINE and HYPERFINE SPLITTINGS ISOTOPIC SHIFTS
LIGHT-POWER: SOME MILLIWATTS	{ ALL ATOMS $\lambda$ DETECTION $\neq \lambda$ LASER 100 MILLIWATTS	SEPARATION OF SUBLEVELS, IN LOW FIELDS ABSOLUTE WAVELENGTHS RYDBERG LEVELS
NO	LIGHT-SHIFTS $\ll$ NAT. WIDTH	COLLISIONS (BROADENING) AT LOW PRESSURE SHIFT
CROSS-OVER	NO	SELECTIVE POPULATION OF CLOSE LEVELS $\rightarrow$ RELAXATION
LINE-SHAPE COMPLICATED VELOCITY CHANGE IN COLLISIONS	LORENTZIAN ALSO WITH COLLISIONS	MOLECULAR SPECTRO SINGLE ROVIBRONIC TRANSITIONS ( $\text{CH}_3\text{F}$ , $\text{NH}_3$ , $\text{NO}$ , $\text{C}_6\text{H}_6$ , $\text{Na}_2$ , $\text{CO}$ , $\text{N}_2$ ...)
TRANSIT-TIME BROAD BEAMS	RAMSEY-FRINGS	TRANSIENTS FREE INDUCTION DECAY (MEASURE $T_2$ ) IN THE DRIVEN REGIME $\rightarrow$ OPTICAL RABI FREQUENCY
LOWER LEVELS	HIGHER LEVELS	RAMSEY FRINGS TWO-PHOTON DISPERSION REFRACTIVE INDEX DEPENDS ON LIGHT-INTENSITY $\rightarrow$ BISTABILITY FOUR-WAVE MIXING



④			
OLD TABLES			
BIRABEN			
GIACOBINO			
EXPT			
THEORY			
ACAD			
PEKERIS			
SCHIFF			
DIFFERENCE			
TH - EXP			
CALCULATED			
LAMB SHIFT			
⑤			
HELIUM $\text{cm}^{-1}$			
OLD TABLES			
BIRABEN			
GIACOBINO			
EXPT			
THEORY			
BLANCHARD			
DRAKE			
DIFFERENCE			
TH - EXP			
CALCULATED			
LAMB SHIFT			

$3S$	$3P$	$3D$
6 — <u>5700 Å</u>	6 — <u>5647 Å</u>	
5 — <u>5970 Å</u>	5 — <u>5870 Å</u>	
4 — <u>6568 Å</u>	4 — <u>6330 Å</u>	



# DOPPLER-FREE TWO-PHOTON LINE-WIDTH ⑧

## EFFECT OF TRANSIT TIME $w_0/u$

{ through Gaussian light beam (waist radius  $w_0$ )  
with the radial velocity  $v_z$

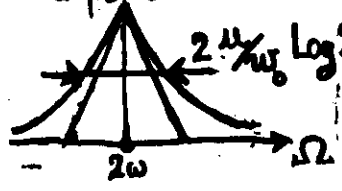
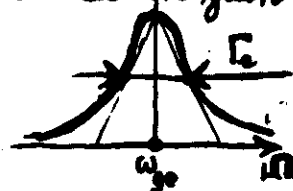
Maxwellian  $f(v_z) = \frac{2v_z}{u^2} e^{-v_z^2/u^2}$   $u^2 = v_z^2 = \frac{2kT}{m}$

⇒ line shape:

$$P(\omega) \approx \int_{-\infty}^{+\infty} d\Omega \frac{\Gamma/2}{(\Omega - \omega_{ge})^2 + \Gamma^2/4} e^{-\frac{|\Omega - 2\omega|}{u/w_0}}$$

Convolution: Lorentzian

double exponential



BORDE  
BIRABEN

## EXPERIMENT ON SODIUM (3S → 4D)

	broad curve	narrow
light beam waist $w_0 =$	25 $\mu$	50 $\mu$
Natural width $\frac{\Gamma_0}{4\pi} = \frac{1}{4\pi\tau}$	1.6	1.6 MHz
Transit broadening $\frac{\text{Log} 2}{2\pi} \frac{u}{w_0}$	2.8	1.4 MHz
residual collisions, jitter	0.9	0.9 MHz
Total width	5.3	3.9 MHz

## ISOLATOR

LASER  $\omega_L$

LENS

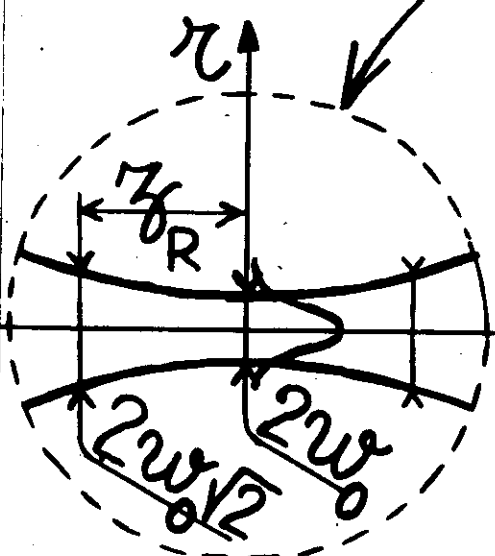
LOCK-IN

PZT

LENS

MONOCHROMATOR

PM

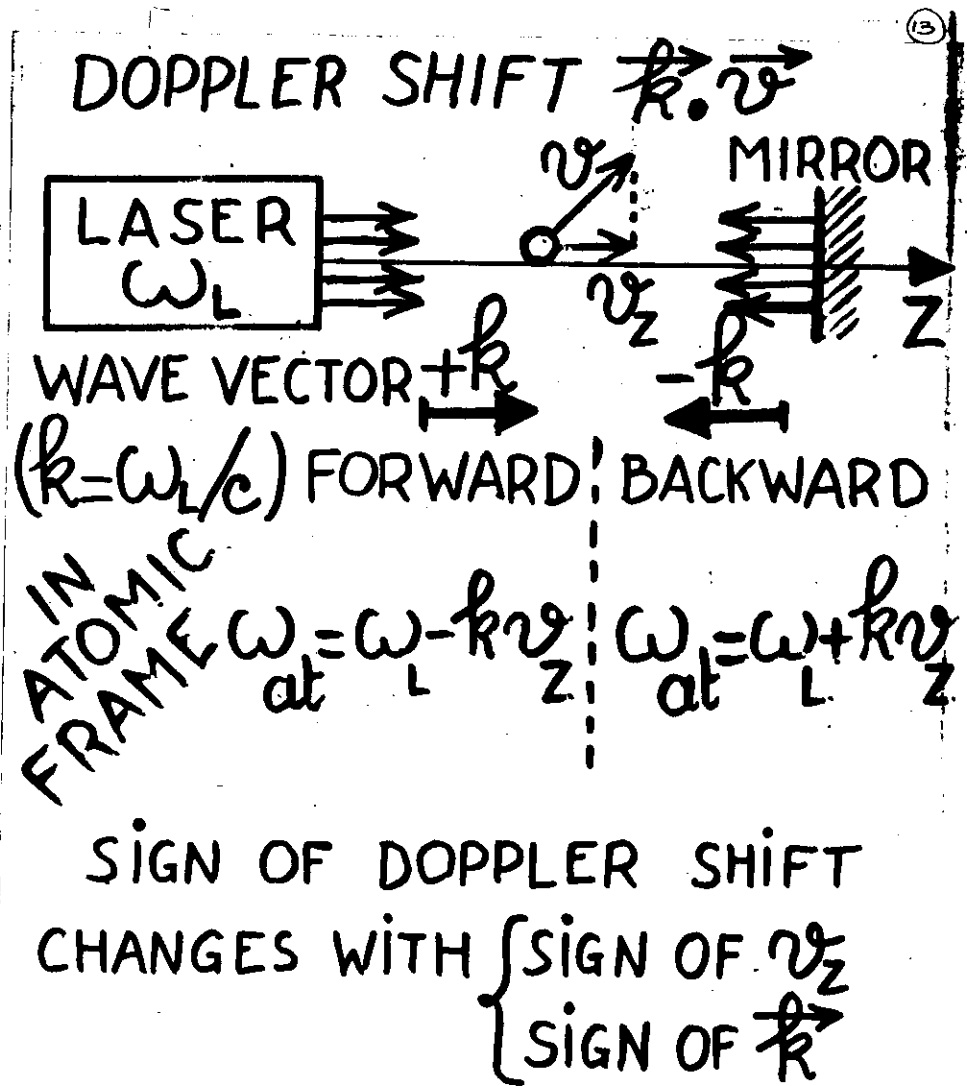
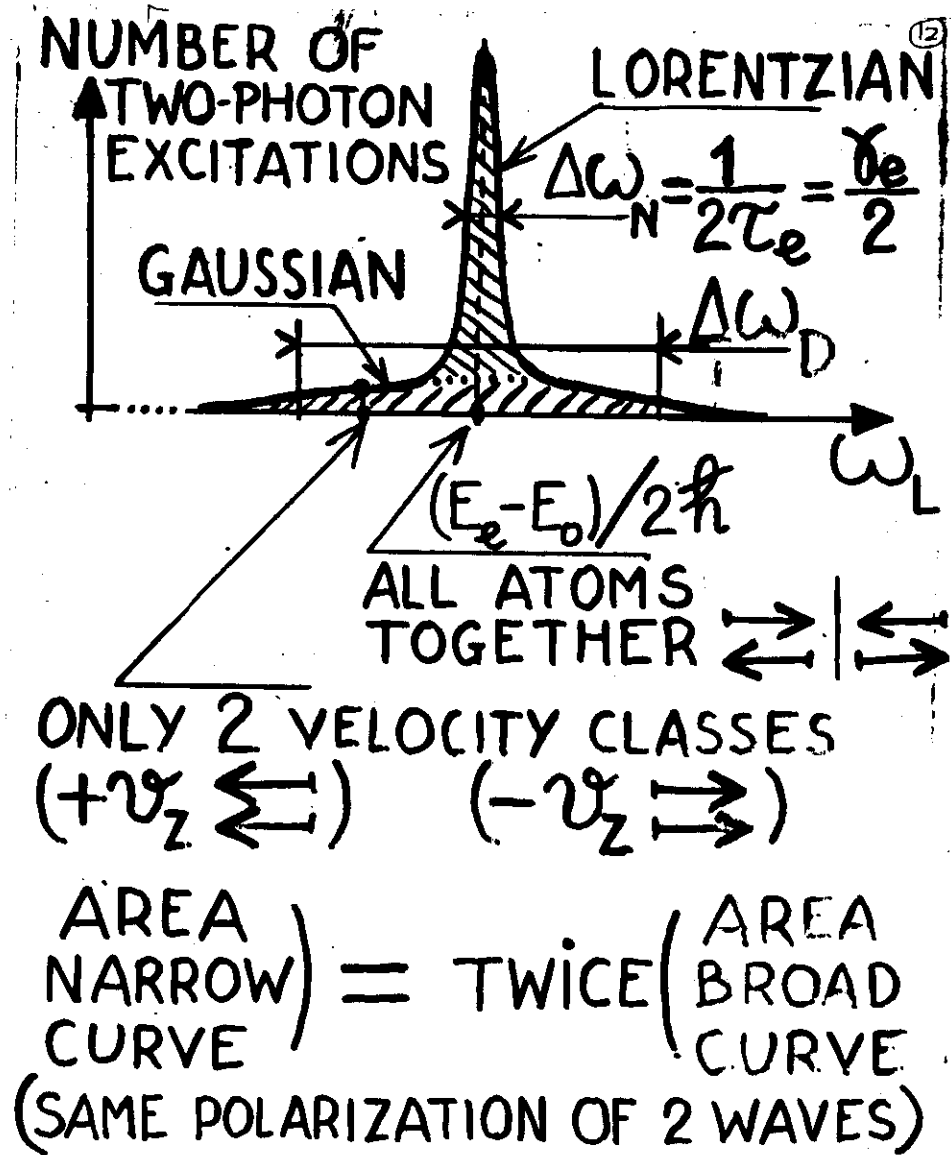


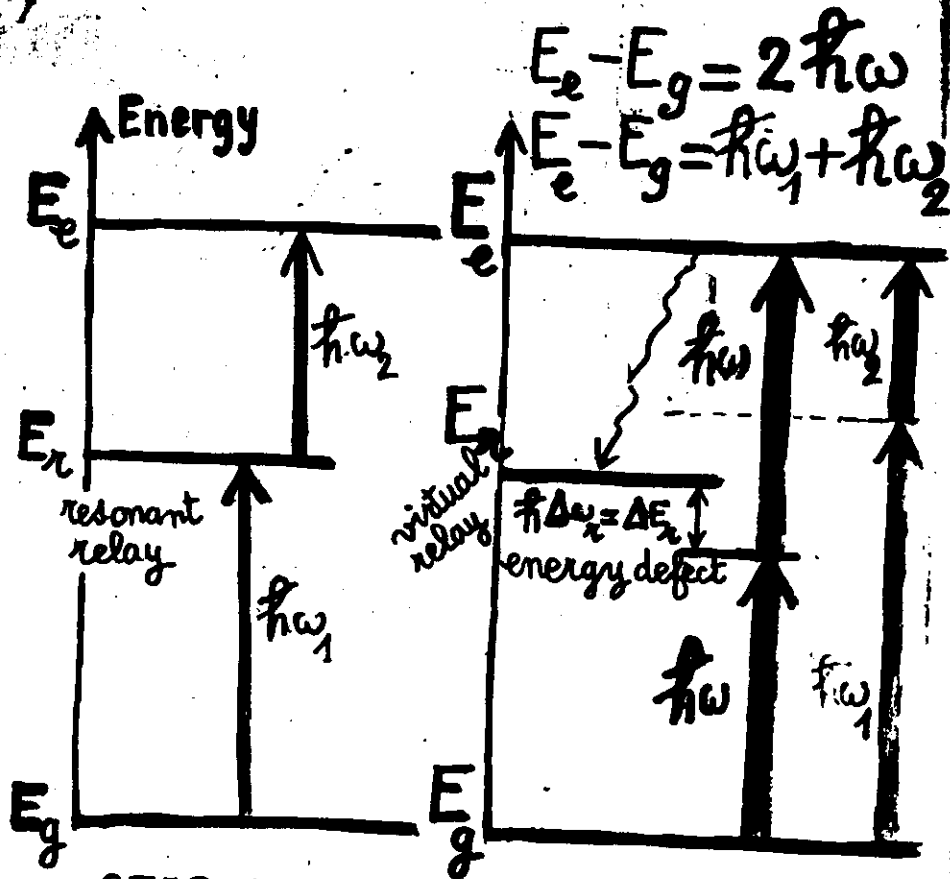
$$\Delta\omega_{tr} = \frac{u}{w_0} \text{Log} 2$$

$$u = \sqrt{v_z^2} = \sqrt{\frac{2kT}{m}}$$

(TRANSIT TIME  $\frac{w_0}{u}$ )





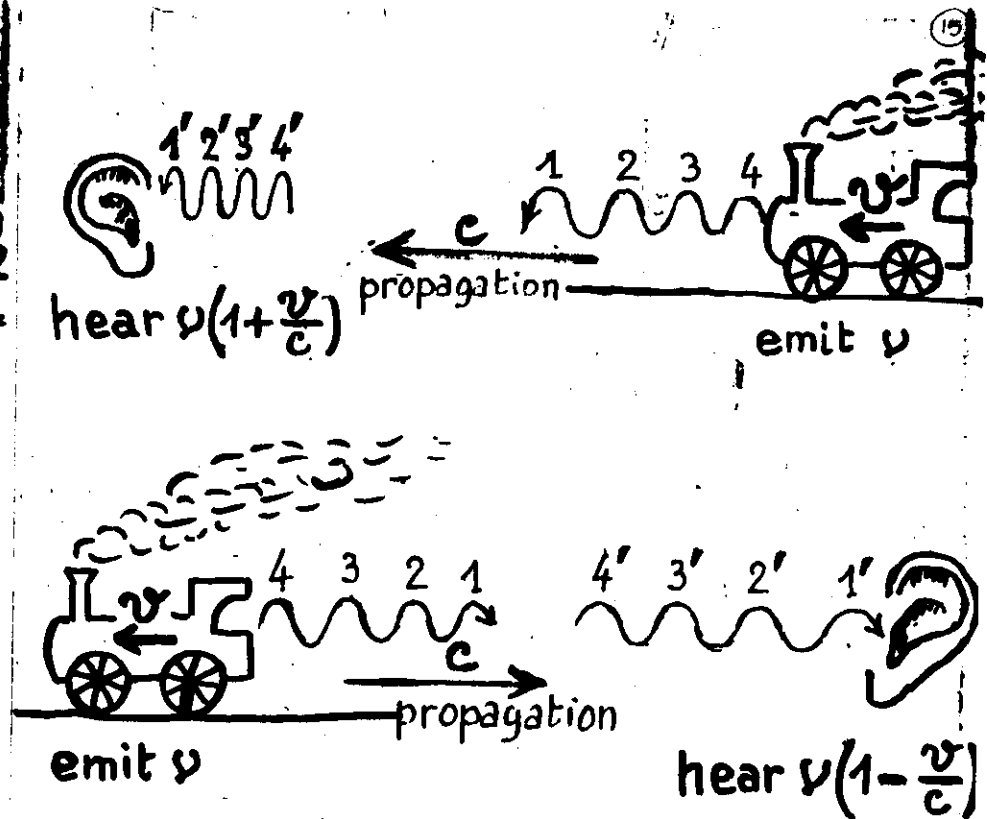


STEP WISE  
EXCITATION

TWO-PHOTON  
EXCITATION

(uncertainty principle)  $\Delta t \sim \frac{1}{\Delta\omega_r} \ll$  all other times

in optical range theory MARIA GÖPPERT-MAYER (1931)



DOPPLER-FIZEAU effect

$v$  atomic velocity  $\sim 10^2$  to  $10^3$  m/s

$c$  light velocity  $\sim 3 \cdot 10^8$  m/s

$$\Delta\nu = \nu \frac{v}{c} \sim 10^9 \text{ Hz} = 10^3 \text{ MHz}$$



labo. « Spectro. Hertz. de l'E.M.S. »  
 { Ecole Normale Supérieure  
 Université P. et M. Curie (PARIS 6)

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J. BAUCHE

labo. Horloge Atomique

A. BRILLET

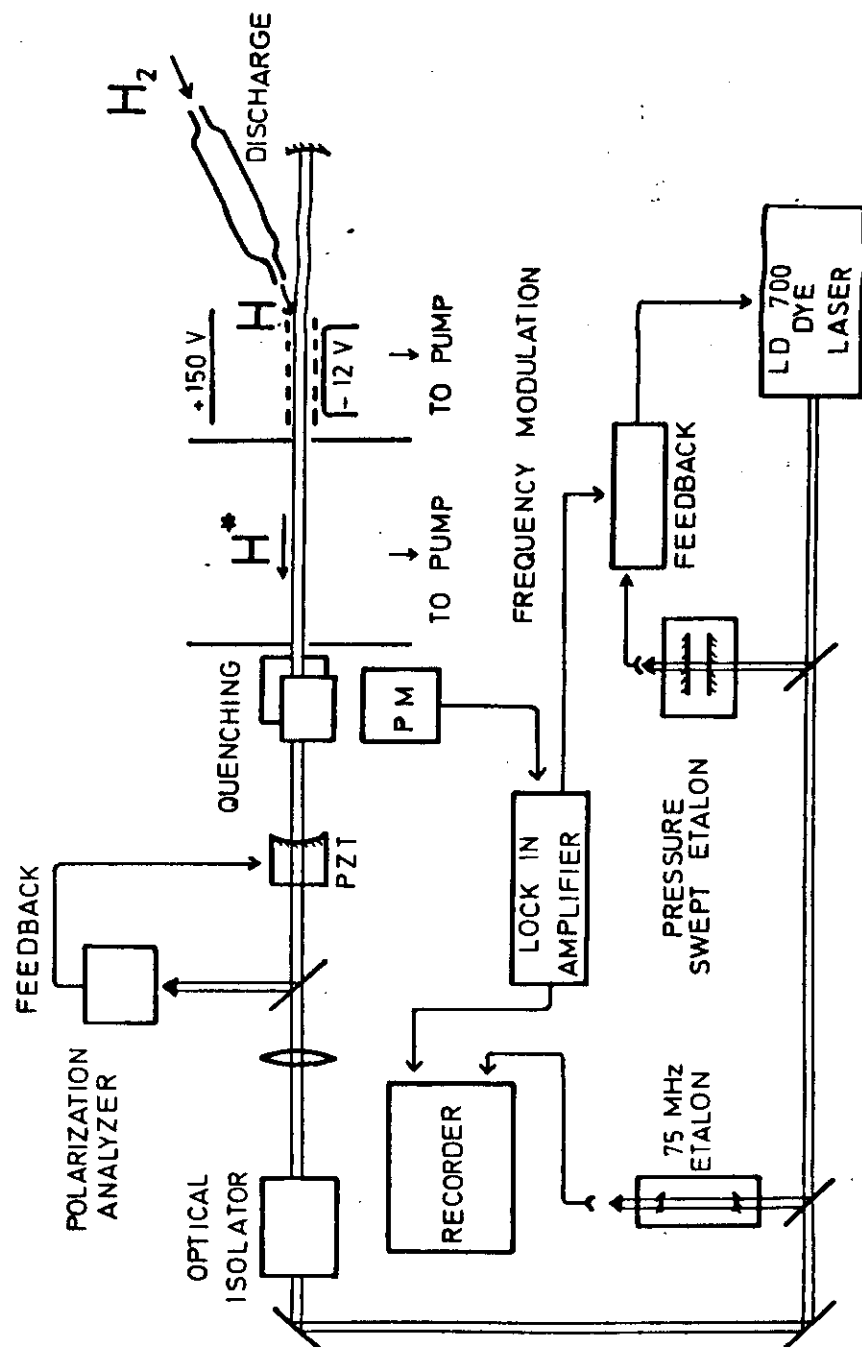
initial idea common with:

L. VASILENKO

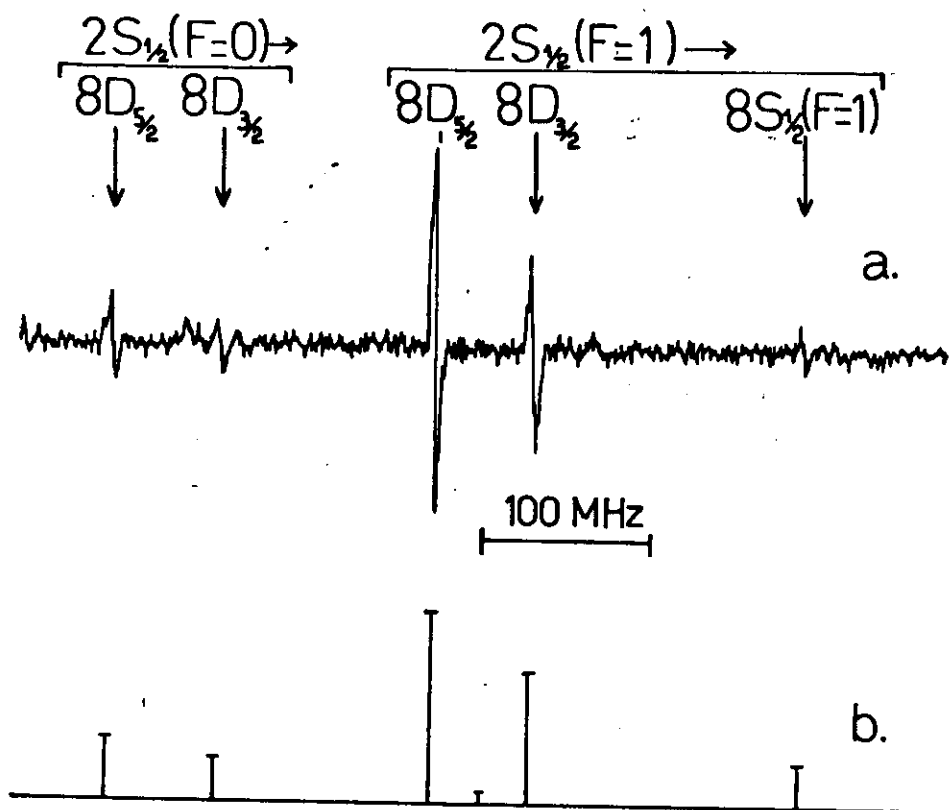
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