First US-Japan Seminar

Dick, Hiroshi and Claud in Norway

Good old times in laser researches at Boulder laboratories

US-Japan Seminar August 23-25 2006

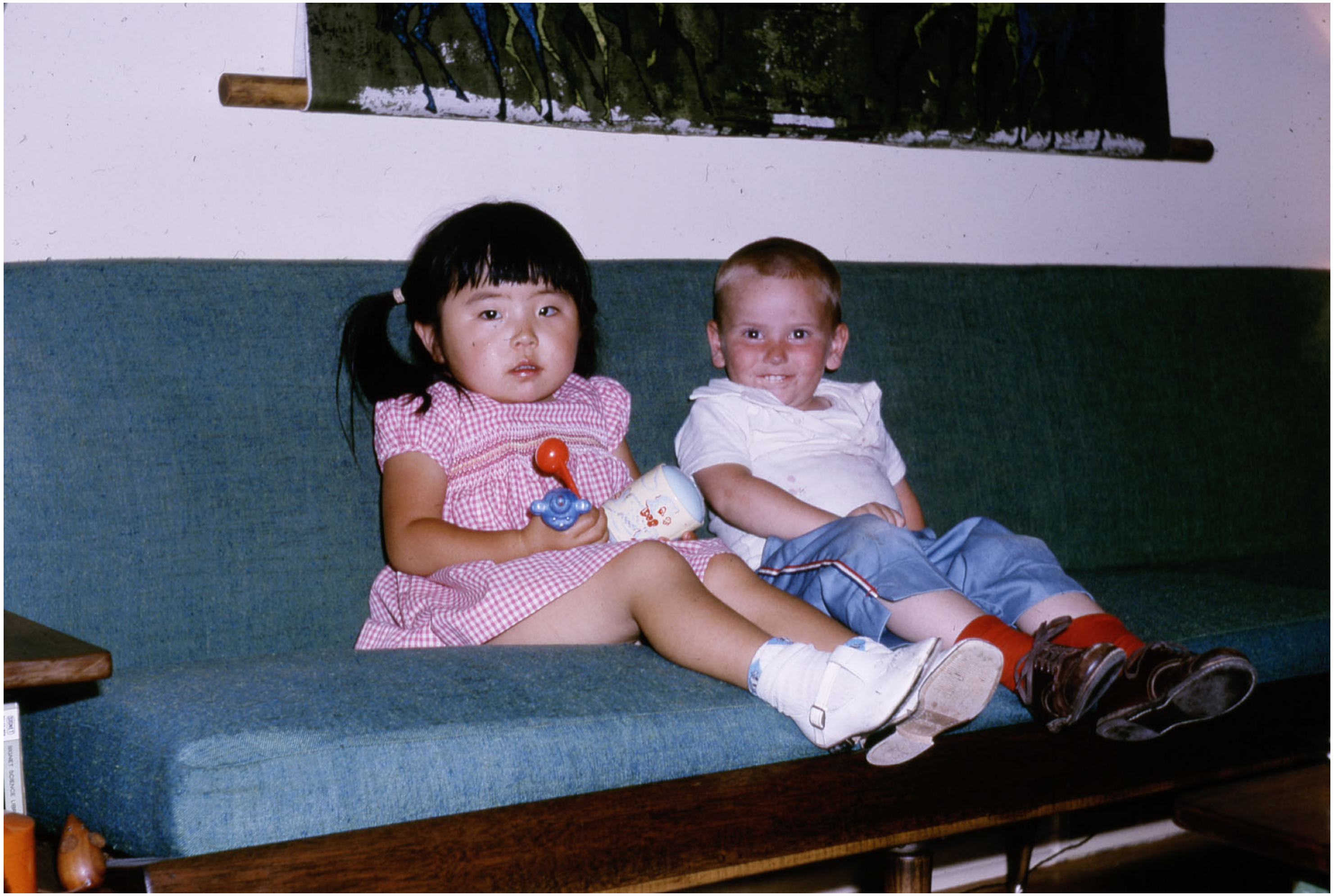
Held at Beaver Run Conference Center

Breckenridge, Colorado

By H. Takuma

Borrowed from Jan’s Lecture Note

Kaoli and Thomas (1964)



ADVANTAGE of LASERS (1)

High Photon Density in a Single Optical Mode

i.e. Intense Temporary Coherent Photons

→ Nonlinear Effects

Harmonic Generation, Stimulated Scatterings,

Coherent Transient Effects, etc., etc.

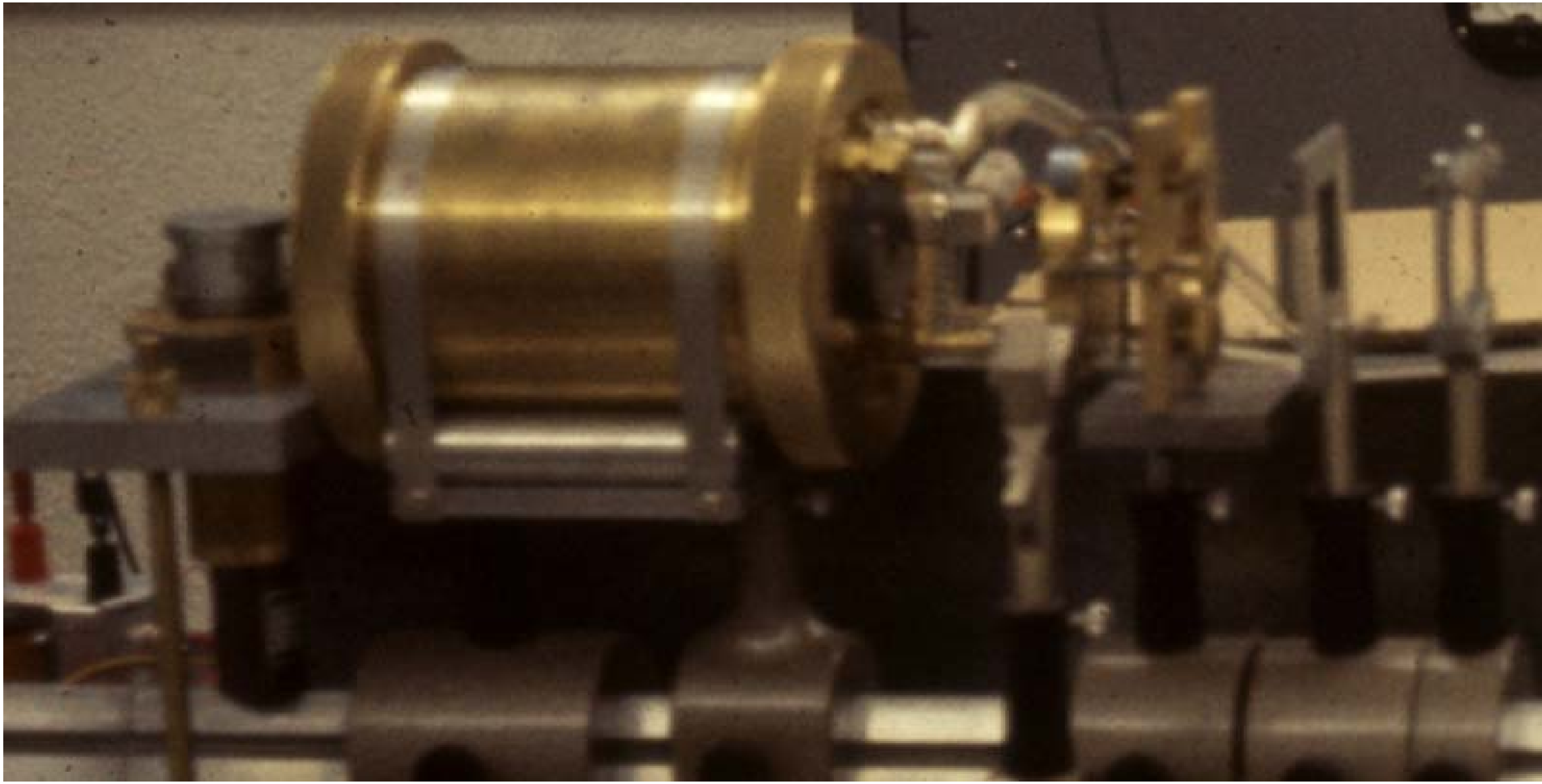
ADVANTAGE of LASERS (2)

Wavelength and the Phase of the Photons
Depend Entirely on the Optical Cavity
i.e.
Frequency and Phase are Stable
as Far as the Optical Cavity is Stable

↓

New Standard of Time, Frequency & Length

The Finest High Power Laser in 1963
Q-Switched Ruby Laser by Don Jennings
at NBS (NIST) Boulder Laboratory



The First Subject of H.T. in Boulder

- Demonstration of Coherent Raman Radiation to Build Up in an Optical Cavity.

Most People Said “No!” at That time.

J. Hall Said “Try It.” after a Full Day Discussion.

Raman Scattering (Semi-Classical)

$$P_{-1} = \chi_{-1} E_L$$

$$\frac{dW_{-1}}{dt} = \left\langle \frac{dP_{-1}}{dt} \cdot E_{-1} \right\rangle_t - \frac{\omega_{-1} W_{-1}}{Q_{-1}}$$

Raman Scattering (Quantum Mechanical)

$$|0\rangle_M |n_L\rangle_L |n_{-1}\rangle_R \Rightarrow |1\rangle_M |n_L - 1\rangle_L |n_{-1} + 1\rangle_R$$

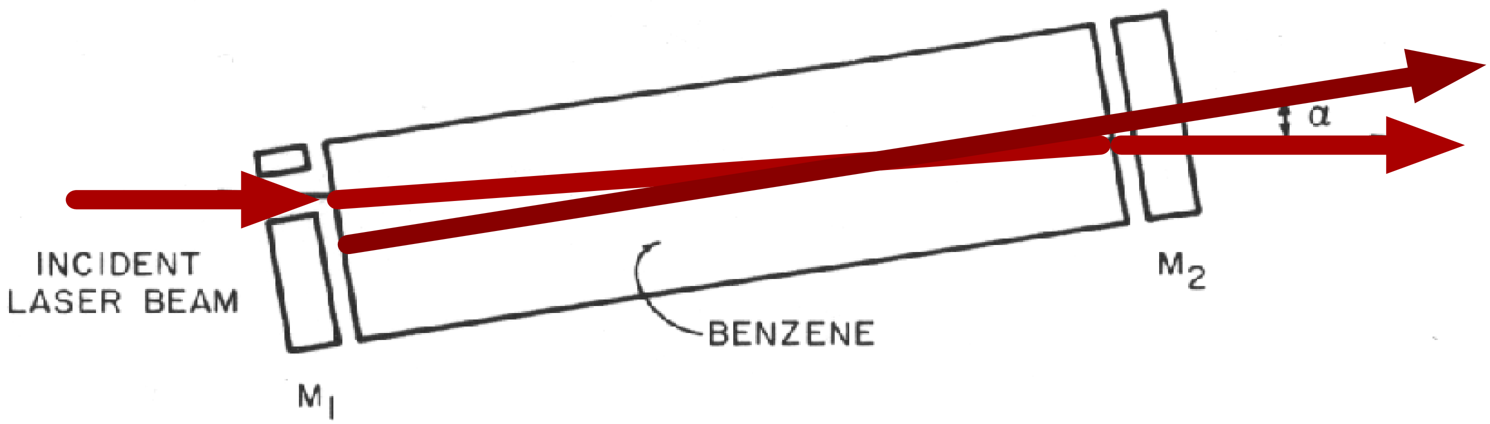
$$\frac{dn_{-1}}{dt} = b_R n_L (n_{-1} + 1) - \frac{\omega_{-1} n_{-1}}{Q_{-1}}$$

Including the Higher Stokes Generation

$$\frac{dn_{-1}}{dt} = b_R n_L (n_{-1} + 1) - b_R n_{-1} (n_{-2} + 1) - \frac{\omega_{-1} n_{-1}}{Q_{-1}}$$

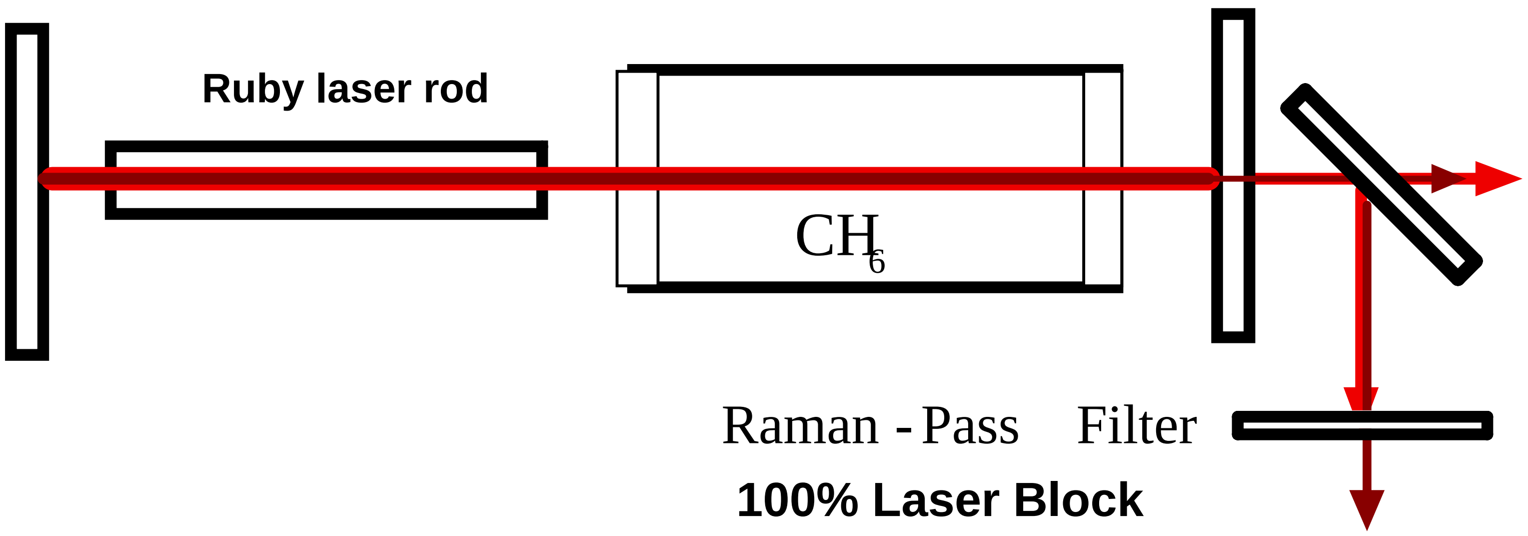
$$\frac{dn_{-2}}{dt} = b_R n_{-1} (n_{-2} + 1) - b_R n_{-2} (n_{-3} + 1) - \frac{\omega_{-2} n_{-2}}{Q_{-2}}$$

RAMAN RADIATION
BUILT UP IN A RESONATOR (1)
Off-Axis Resonator



H.. Takuma & D.A. Jennings, Appl. Phys. Lett.**4,** 185(1964)

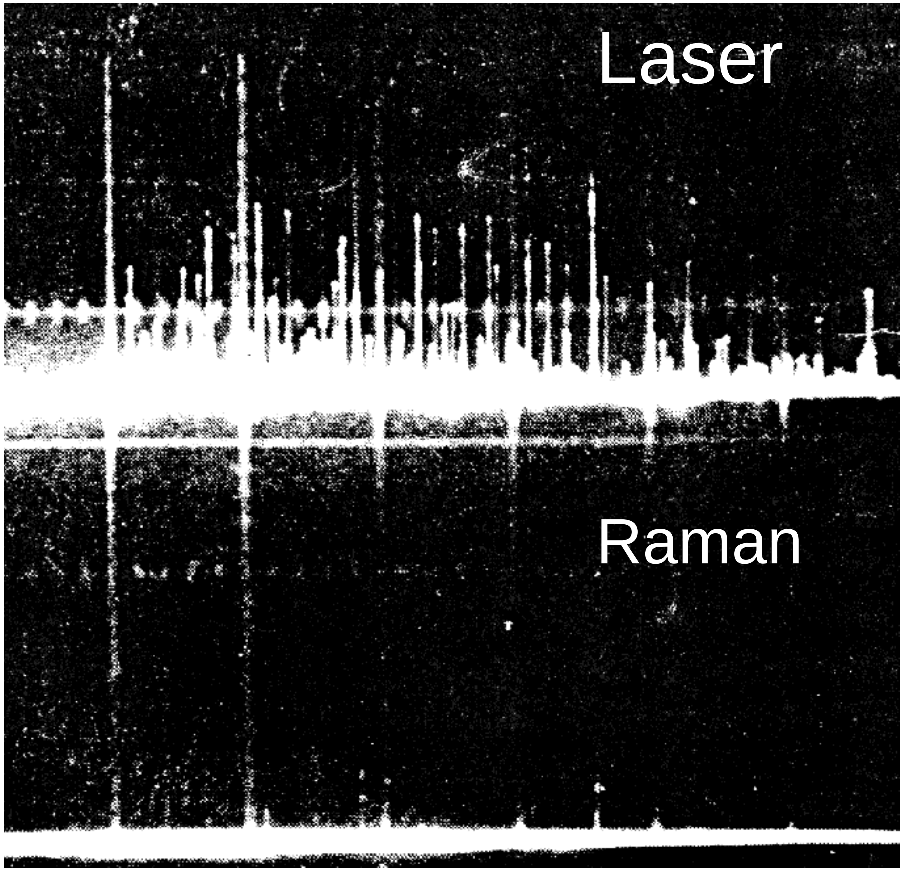
RAMAN RADIATION
BUILT UP IN A RESONATOR (2)
of a Non-Q-switched Laser

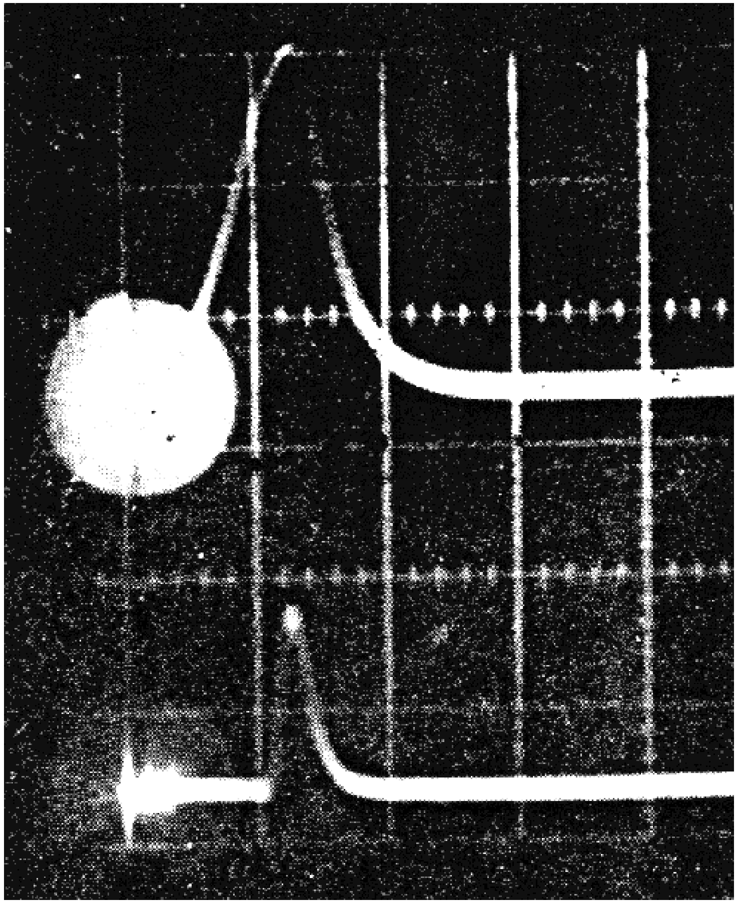


Quantitative Study

H. Takuma & D.A. Jennings, "Characteristics of a Raman Laser Excited in an Ordinary Ruby Laser", Proc. IEEE 53, 146-9 (1965)

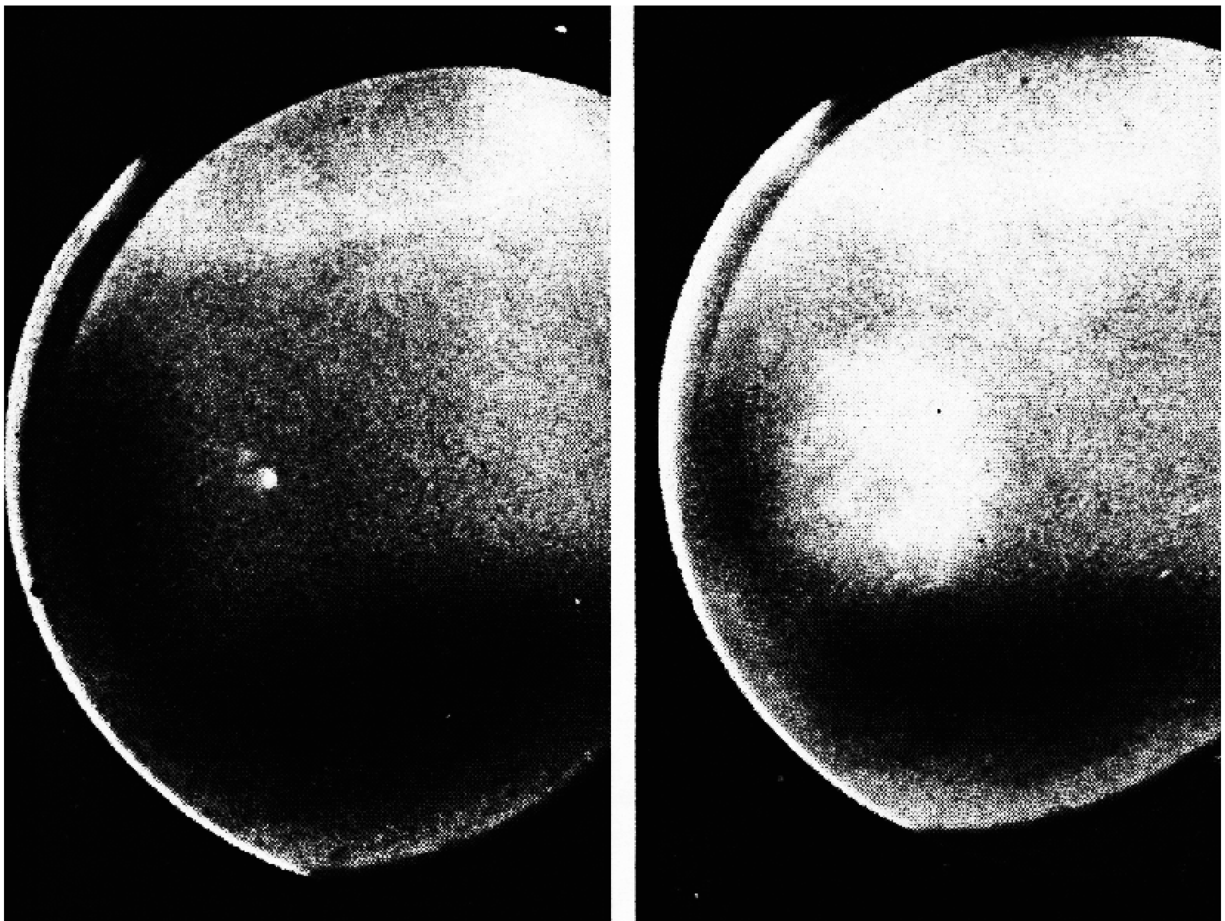
RAMAN RADIATION BUILT UP IN A RESONATOR OUTPUT (3)

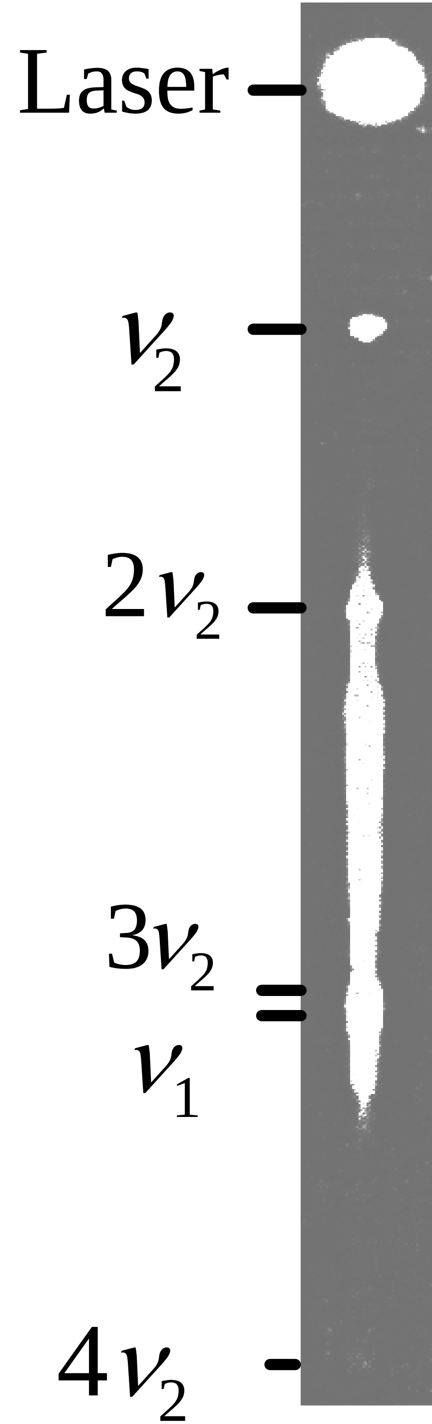




RAMAN RADIATION BUILT UP in a LASER RESONATOR

Near-Field Pat. & Spectrum





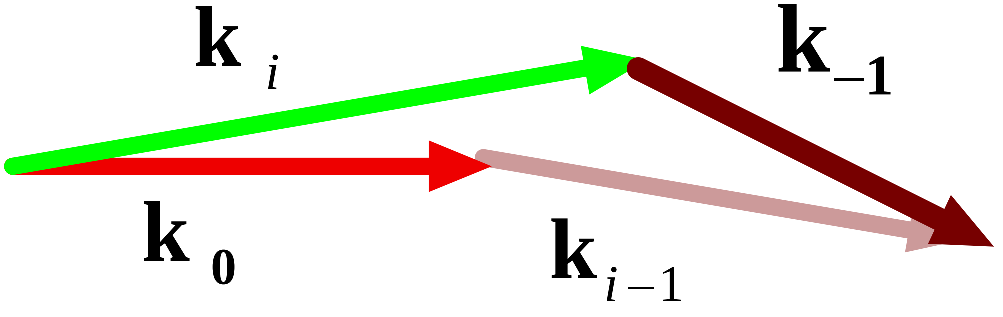
RAMAN RADIATION
BUILT UP in a LASER RESONATOR
Conclusion

- Raman radiation can be built up by the stimulated radiation in an optical resonator
- Laser and Raman radiations are built up in filaments, and every thing fits well with theory quantitatively, if those are taken into account
- Higher order Raman lines and continuum are generated as well as the 1st Stokes

HIGH ORDER
RAMAN RADIATIONS

Stimulated 1-st Stokes Radiation
Generates 2-nd Stokes Radiation
3-rd Stokes →4-th Stokes

. . . .



Anti-Stokes Rings of Benzene Generated by Ruby Laser

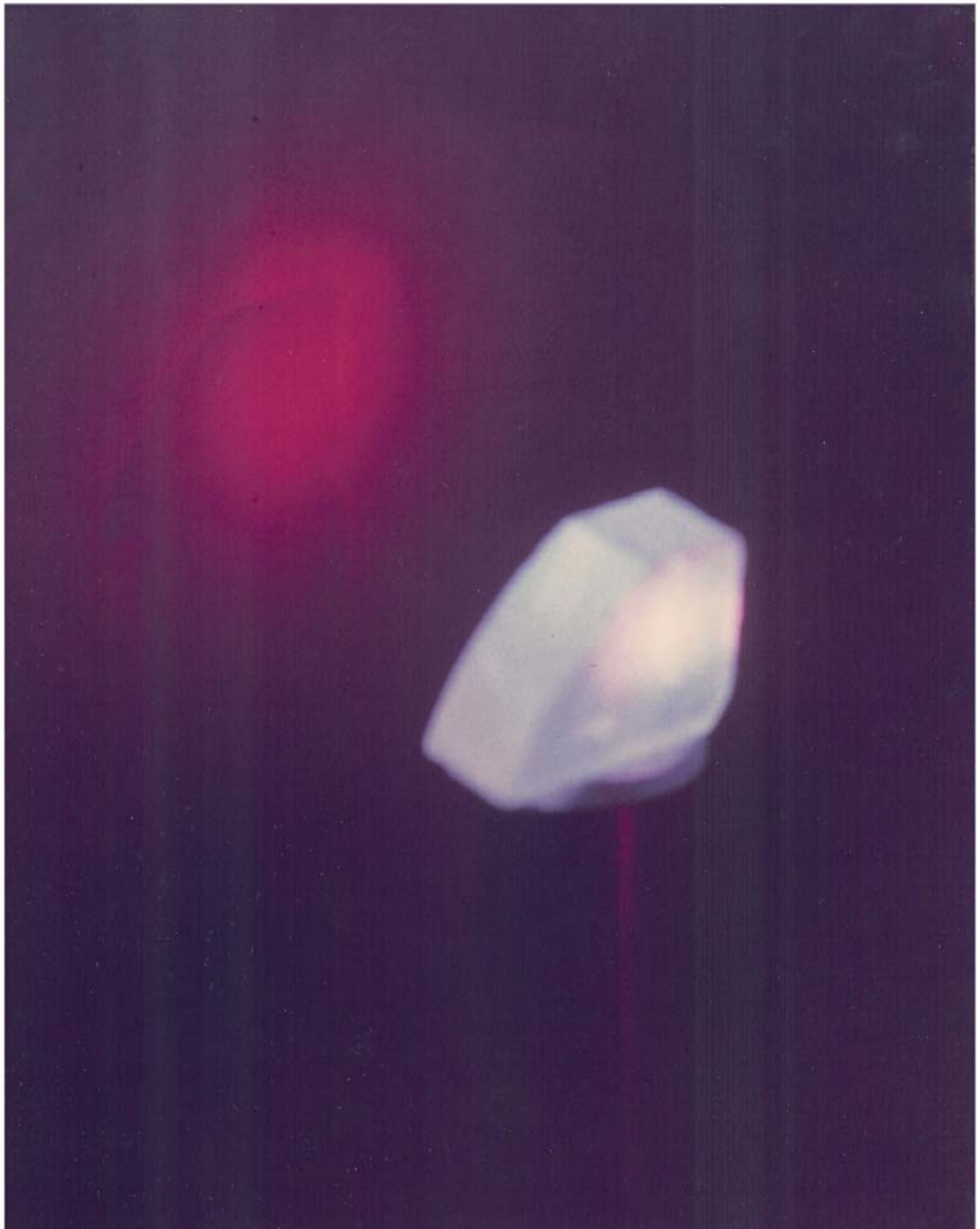
Boulder, 1963

D.A. Jennings

J.A.Hall

& H.Takuma

Unpublished



Two-Photon Excitation of Anthracene Crystal by Ruby Laser

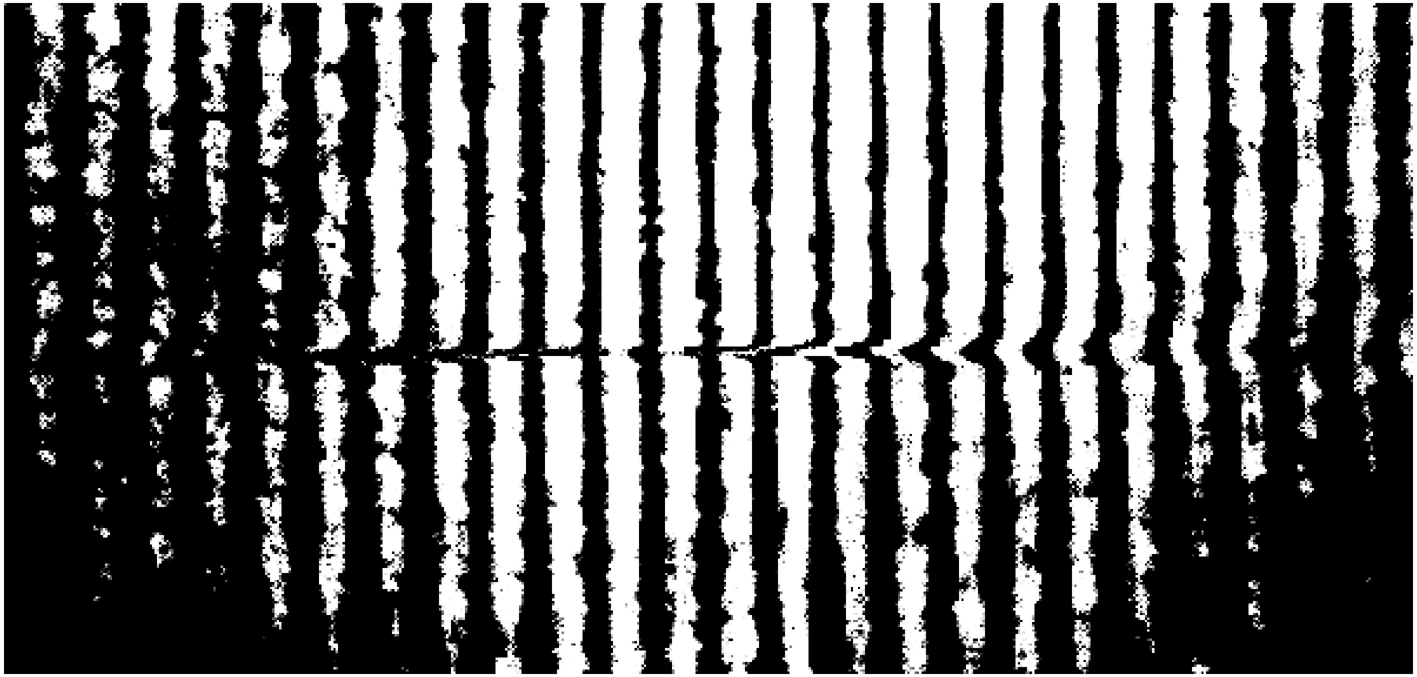
Phys.Rew.L, 1963

J. Hall, D. Jennings, & M. Strickland

Not Energy transfer by Collision i.e. “Stokes’s Law” Does not Apply Any More!

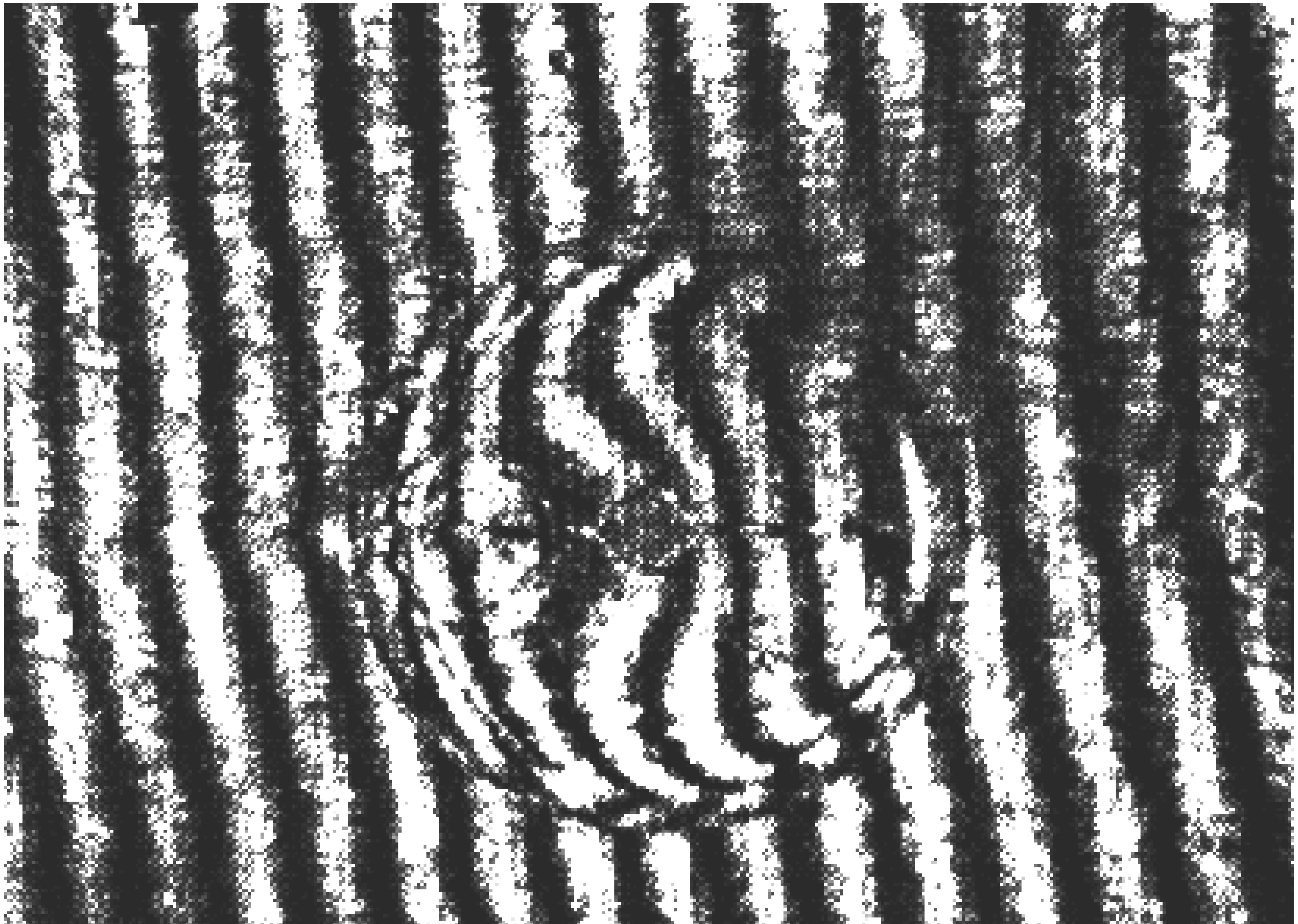
SELF FOCUSING by n_2

$$n = n_0 + n_2 E_{photon}{}^2$$

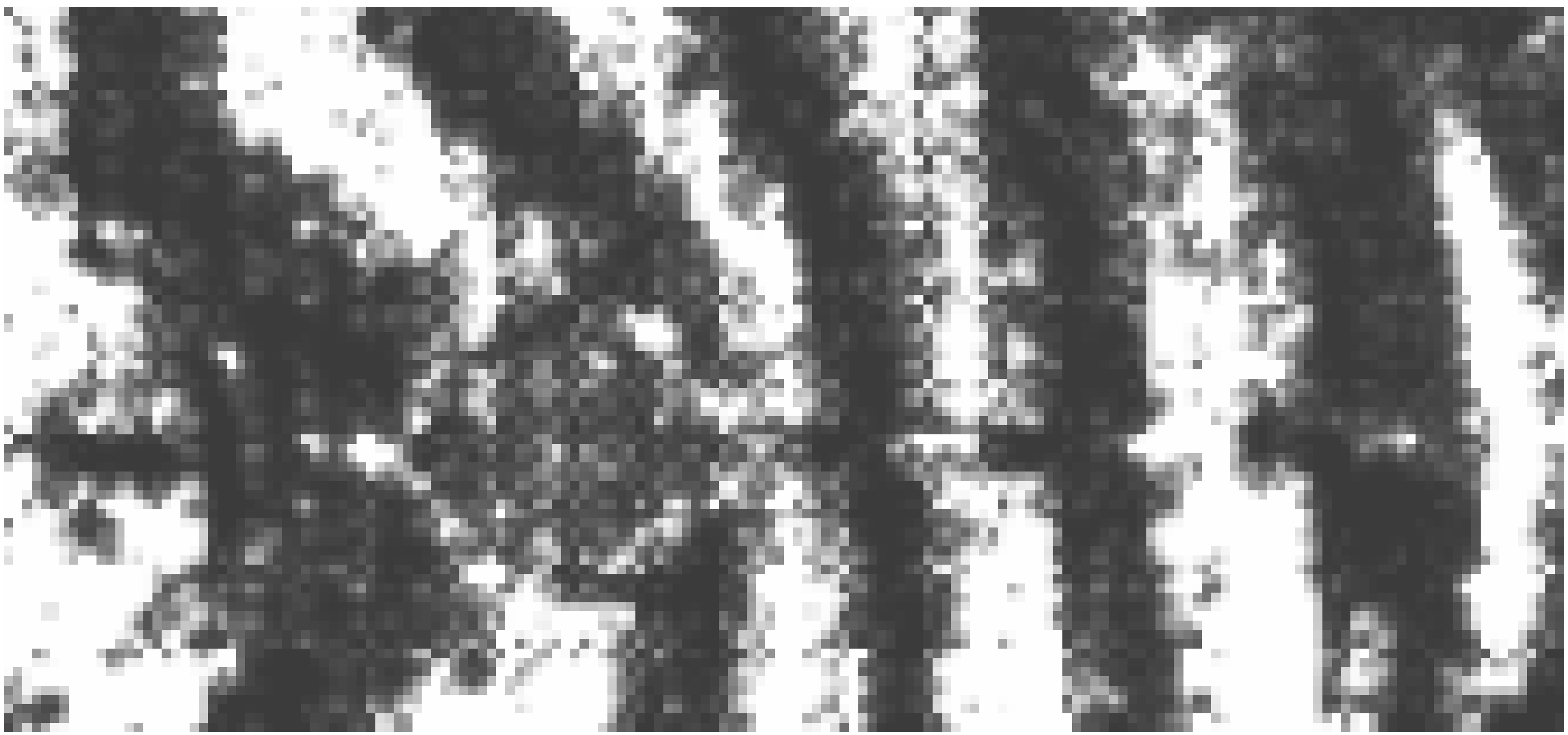


Holographic Interferometry by Saikan & Takuma (19689)

CONFIRMATION of OPTICAL FILAMENT FORMATION by HOLOGRAPHIC INTERFEROMETRY



CONFIRMATION of OPTICAL FILAMENT FORMATION by HOLOGRAPHIC INTERFEROMETRY(2)



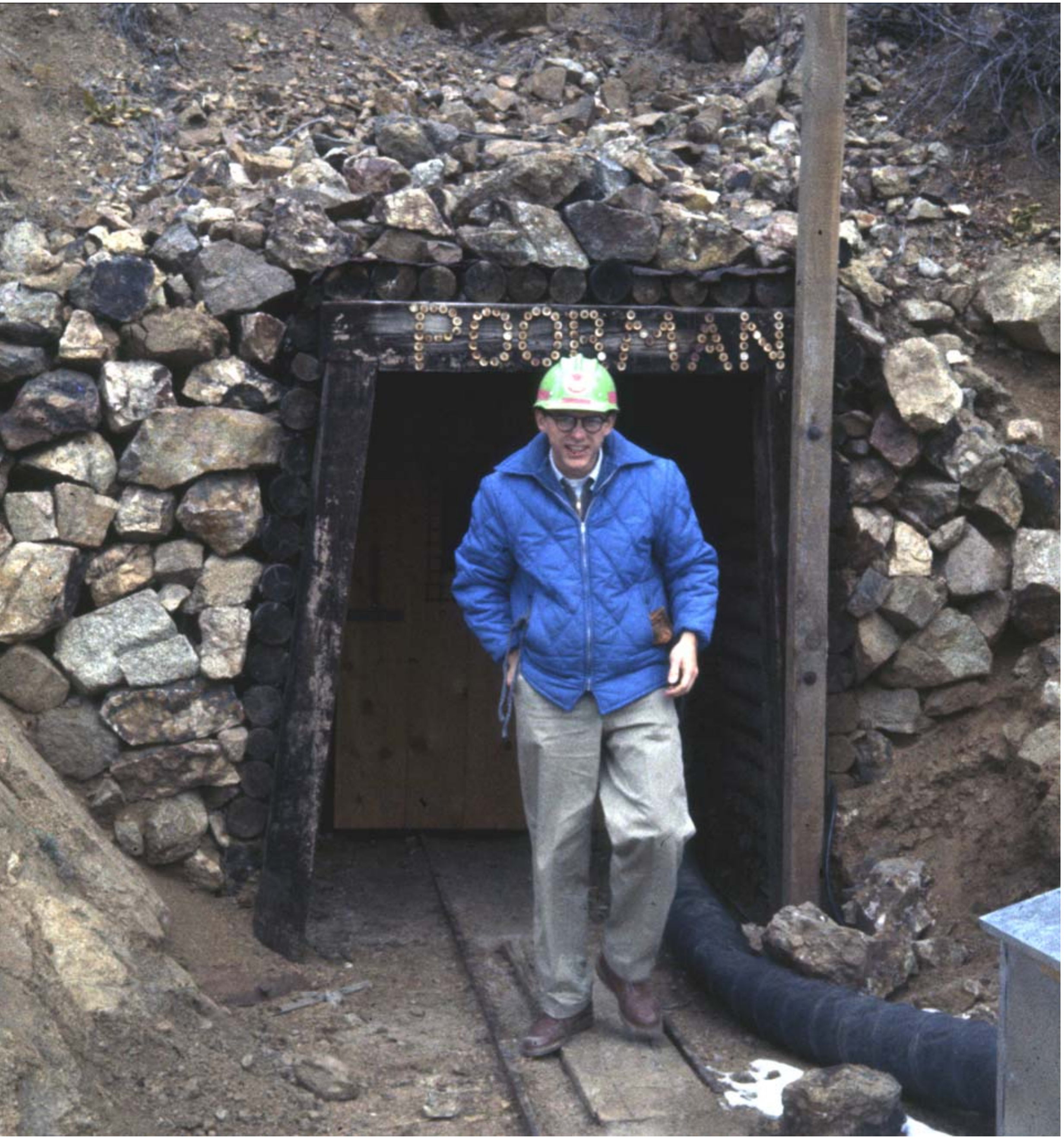
John L. (Jan) Hall

Showing His He-Ne Laser Tube (1963)

He was Invincible in Discussion &
Innovative and Skillful Experimental Physicist

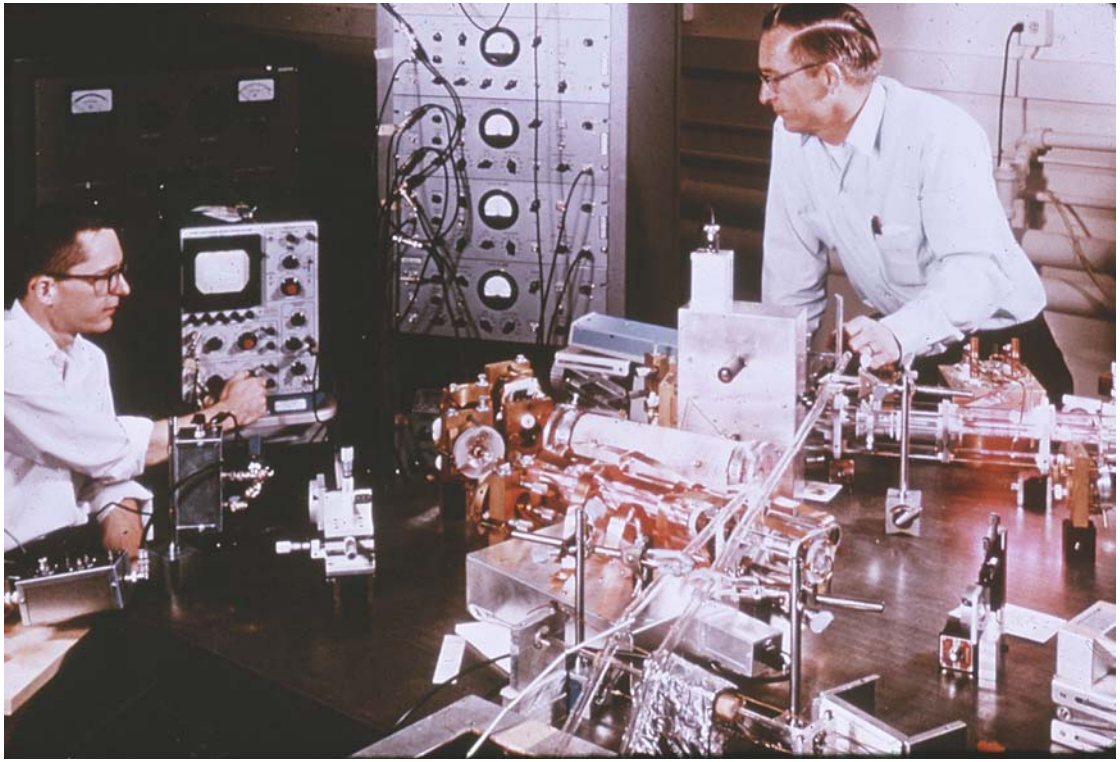
WORKED ON:

Freq.Stabilized He-Ne Laser
Goldmine Interferometer
Two-Photon Absorption
Anti-Stokes Rings
Frequency Beat
Spectroscopy
Etc., etc…………
Always Keeping the Highest
Accuracy in Freq. Standards



Jan Worked
Also on
Gold Mine
Laser
Interferometer

~1965



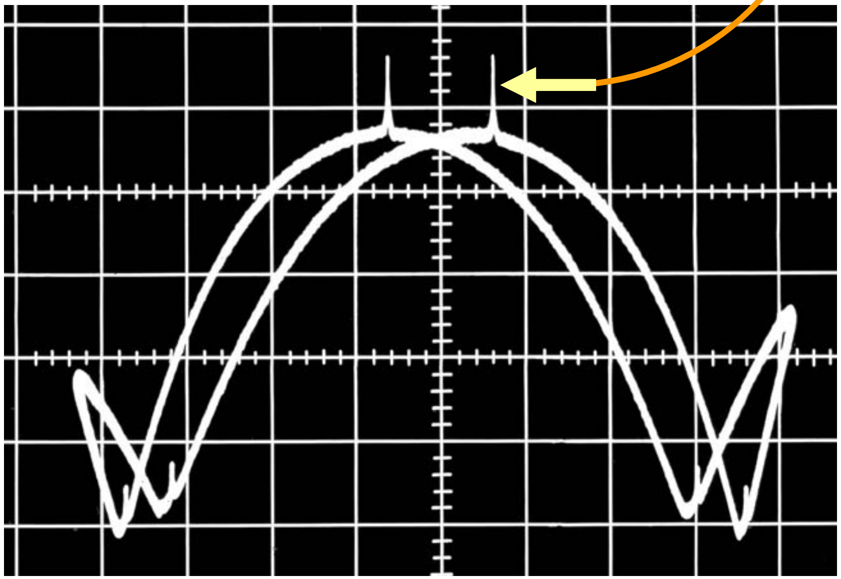
Saturated Absorption in Methane Gas

Line “Q” ~10^9

Reproducibility ~10^{-11}

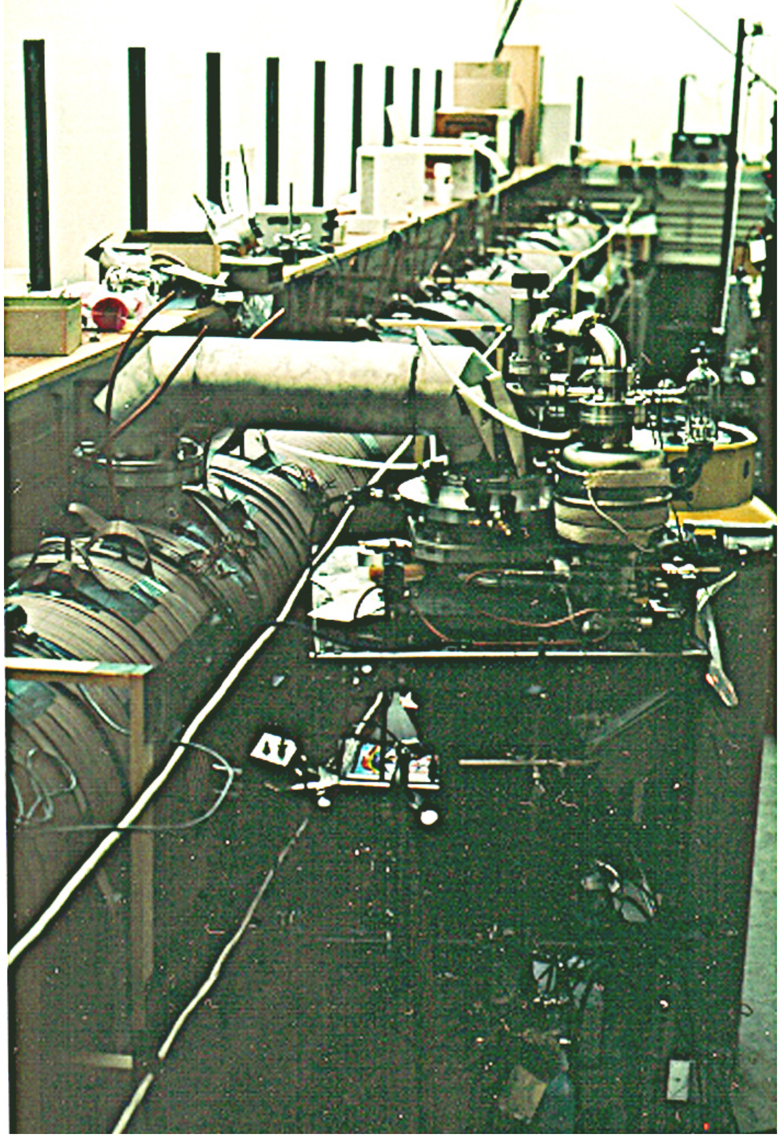
Instability < 10^{-13}

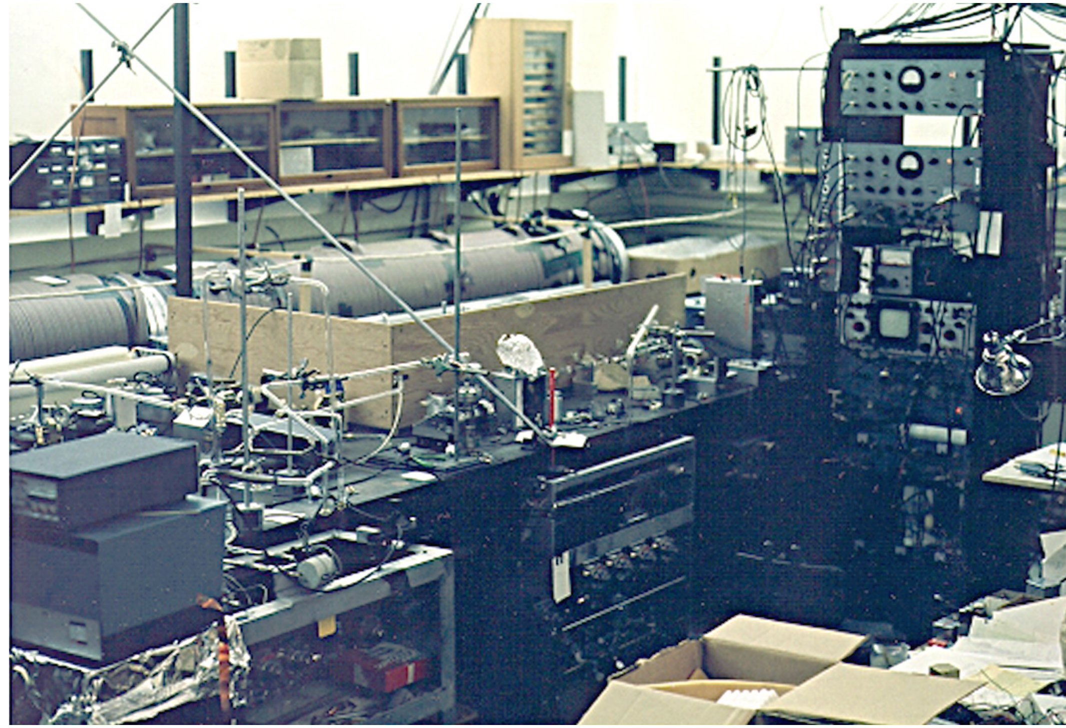
PRL 1969



Two Big Stars,
Jan Hall and Dick Barger ,

Developed Methene Stabilized
HeNe Laser at 3392 nm (3.39 μm)
~ 1972





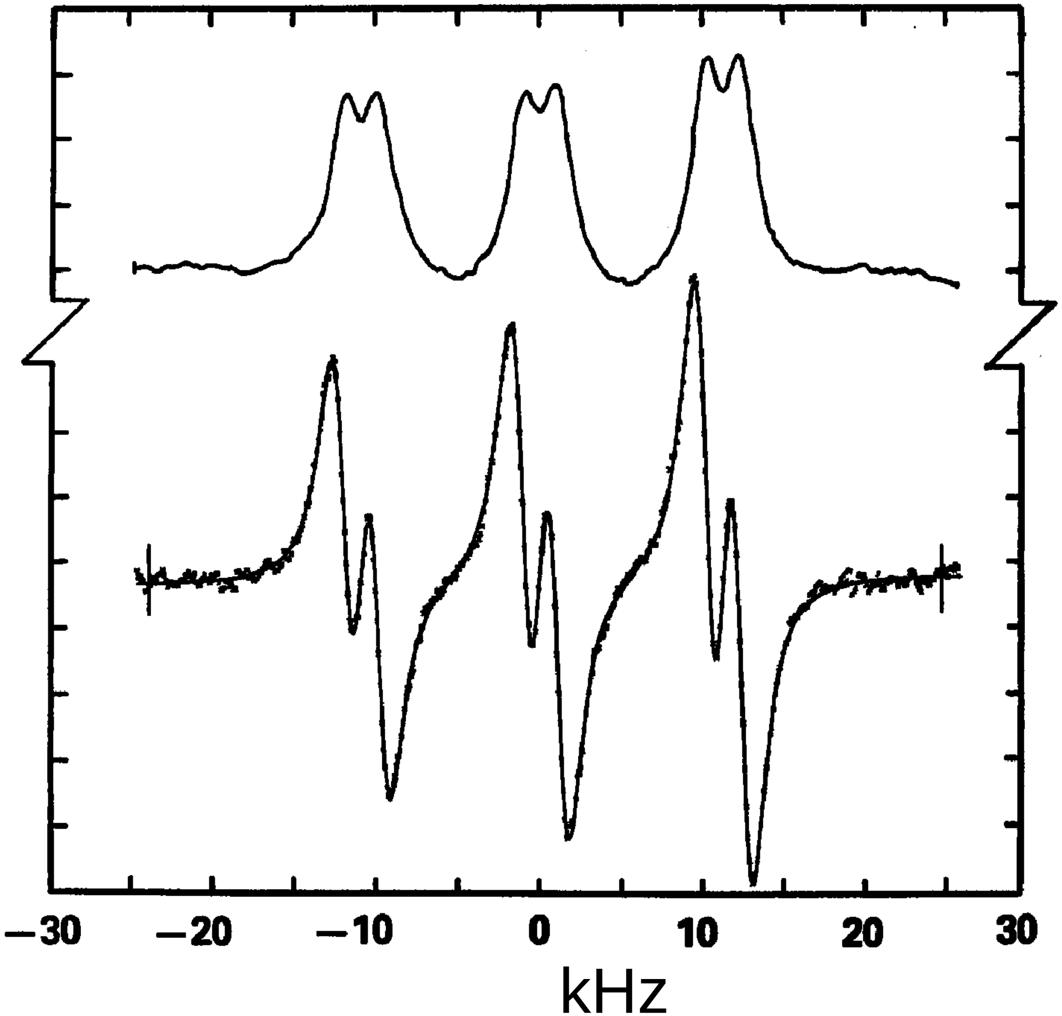
$$\tau_{tr} = w_0 / v$$

$$\Delta\nu \cong 88 \text{ kHz} \cdot \text{mm}/ w_0$$

Transit-time Increase, with Big Beams

K. Uehara, C. J. Borde, and J Hall

Examples of High-Resolution Laser Spectroscopy



Observation of Photon Recoil Doublet

J. Hall, Ch. Borde & K. Uehara
PRL (1976)

Measuring Optical Frequencies

Frequency Starting Point: 9, 192, 631, 770 cycles per second

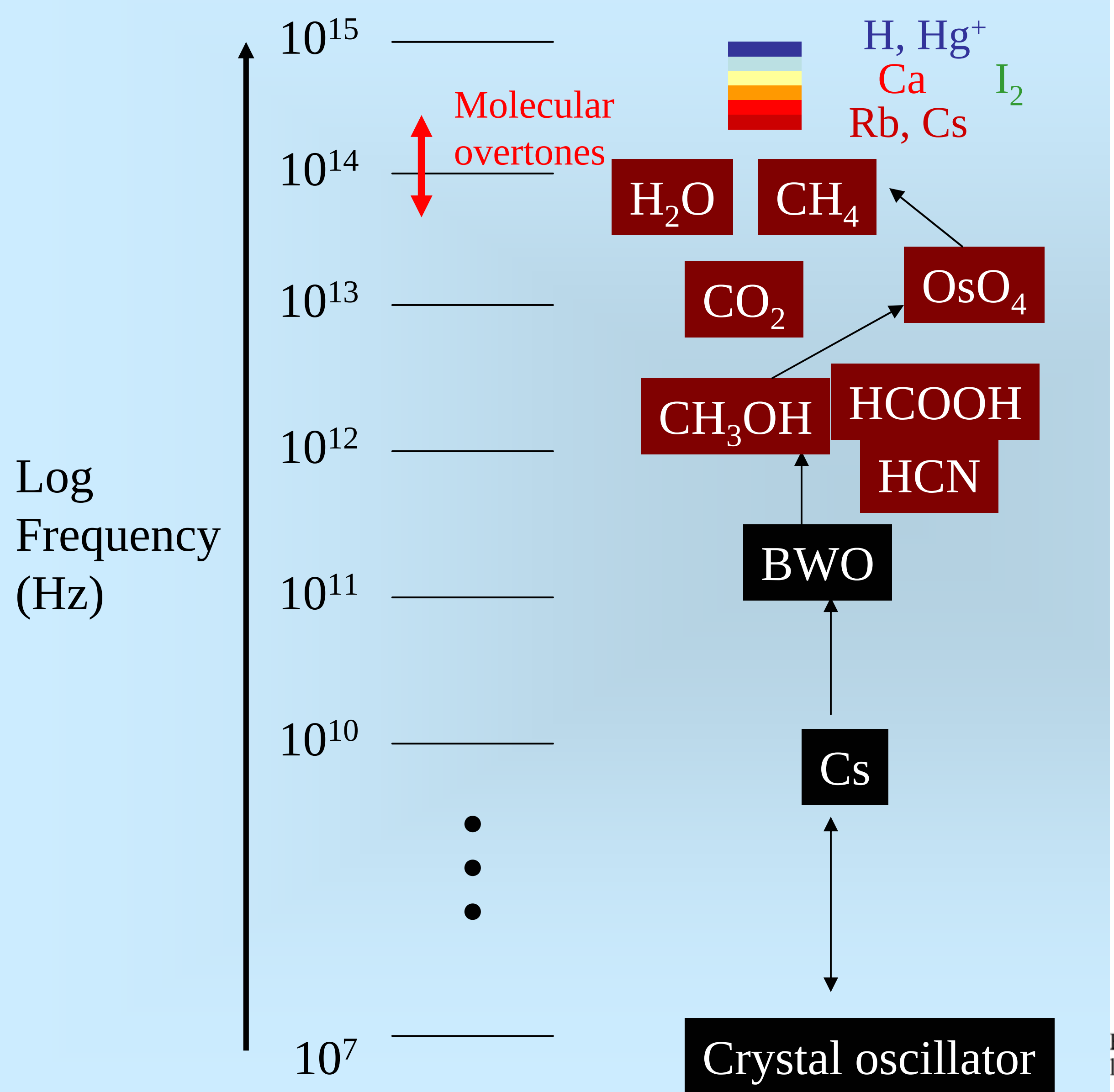
Target Frequency of Mercury Ion: 1 064 721 609 899 143 cps

Frequency Ratio Needed: 115 823.372 081 …

A ratio of 115 Thousand !

How can we **ever** do this?

Frequency spectrum in optical frequency synthesis



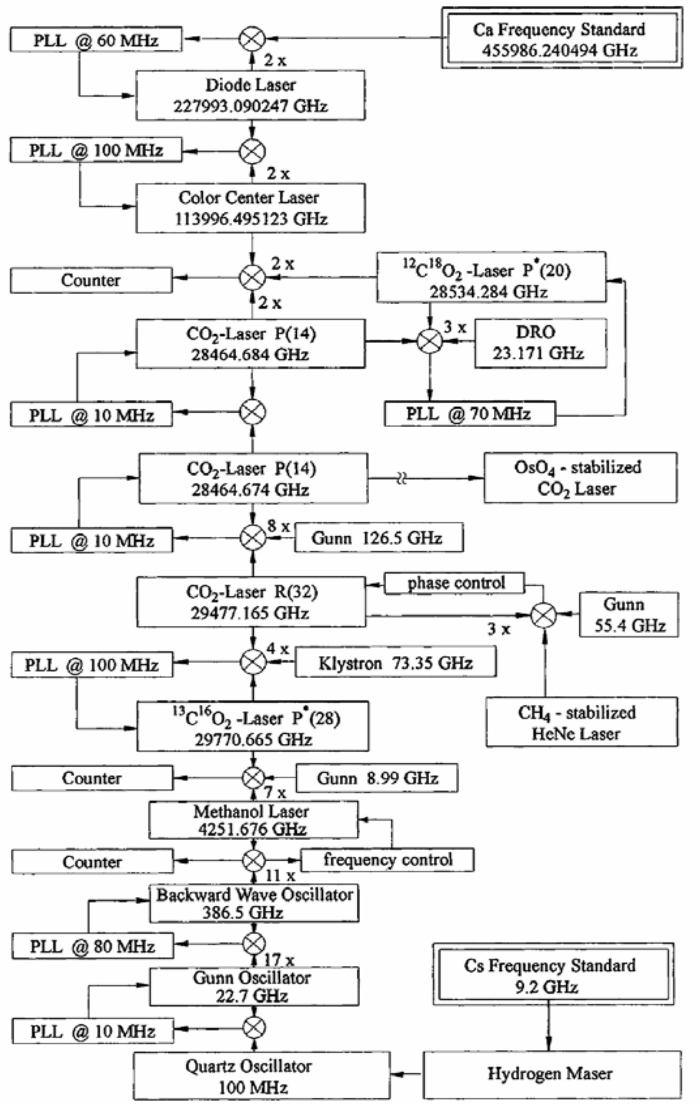
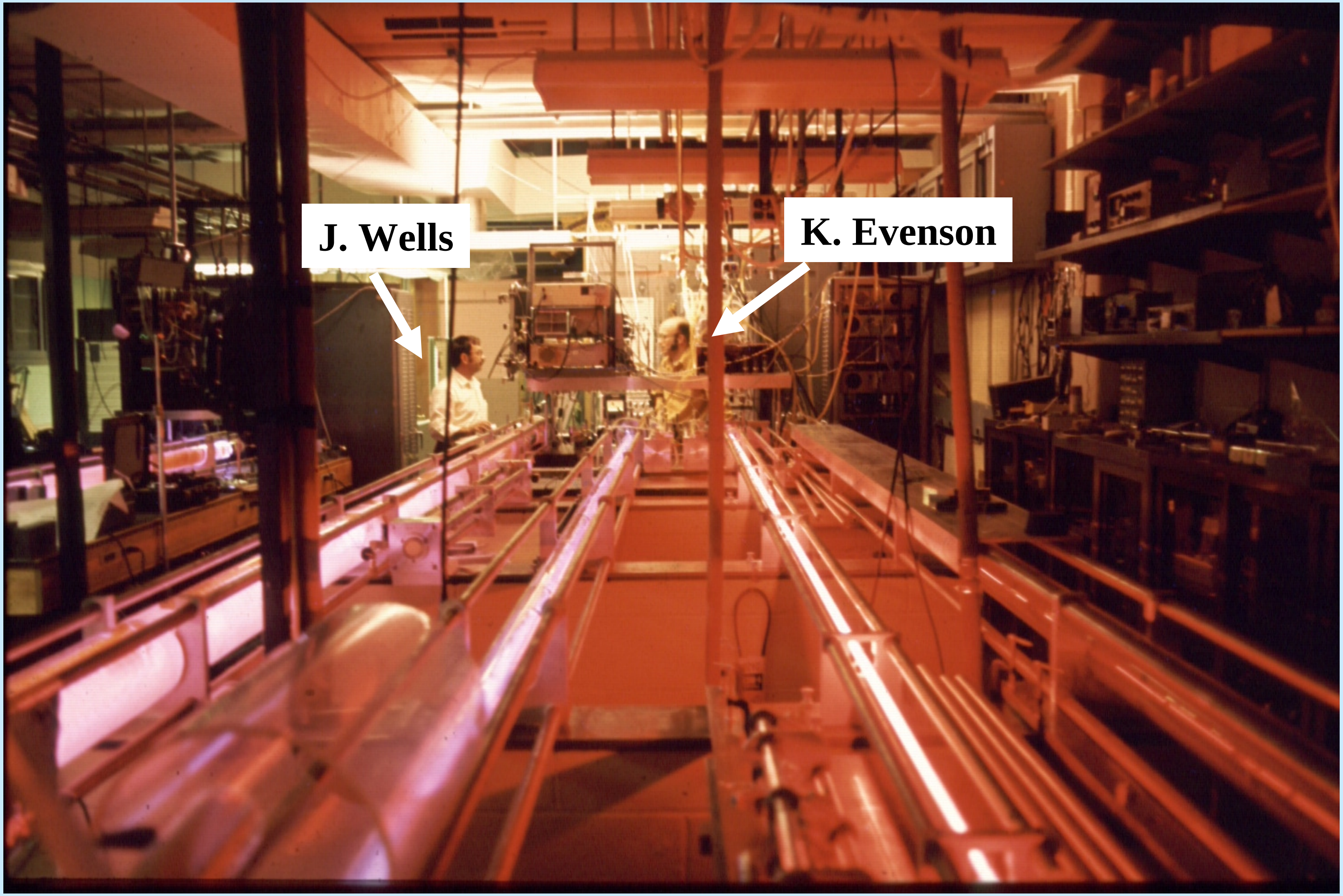


FIG. 1. PTB's frequency chain to the Ca intercombination line (PLL = phase locked loop, details are given in the text).

The First NBS Optical Frequency Chain

NBS (NIST): measurement of speed of light, 1972



J. L. Hall & J. Ye, "NIST 100th birthday", Optics & Photonics News 12, 44, Feb. 2001

IQEC1970

H. Takuma, Jan Hall, Dick Berger

We Shouldn't Forget Two More People:

Ken Evenson & Don Jennings

Expert help with copper H_20 Lines

The new HallLabs
1988

H. Jeff Kimble

Wild West Gambler?

Quantum Optician &

Valentine Professor
of Physics

Caltech - Pasadena

A really dangerous place to visit ! (1988)

Takuma, H
Shimizu, K
Shimizu, F
Ohtsu, M
Barger, D
Winters, M
Hils, D
Wong, NC
Brown, T
Hall, J

Oh, what a wicked World!

Dec.10, 2005 in Stockholm

Still Curious Six Eyes!