High-Power Diode-Laser-Pumped CW Nd:YAG Laser Using a Stable-Unstable Resonator:

Proof of Principle Experiments

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LIGO-G980049-28-M

Aim

To develop a diode-laser pumped, CW, 1μm laser architecture/design for a high power solid-state laser with single mode, single frequency and diffraction limited output, suitable for Gravitational Wave Interferometry.

Main Issues

- Solid-state laser host
- Pump geometry
- Large Mode Volume & good Mode Discrimination: Resonator Choice

Solid-state laser host

We considered neodymium host materials such as: YLF, YAP, Glass, YAG, YVO_4, GSGG:Cr, KGW, BeL, S-VAP, CWO, NGWO and SGGM.

We have chosen **Nd:YAG**

- due primarily to its good thermomechanical properties
- particularly high thermal conductivity.

Pump Geometry

- **rectilinear slab geometry**
  - eliminates stress induced birefringence.

- **zigzag optical path**
  - reduces thermal and stress induced focusing.

- **side pumped and side cooled**
  - producing a scalable geometry.

(ie: pumping & cooling in the same plane, independent of crystal height & length)

- **pumped by fibre coupled diode-lasers**
  - for high inversion densities.
  - allow pumping of specific region of gain medium.

Resonator Choice

Require: • large mode volume
• good mode discrimination
• high output power.

⟶ Use an Unstable Resonator.

Unstable resonators suit high gain systems - however CW Nd:YAG is a low gain system.

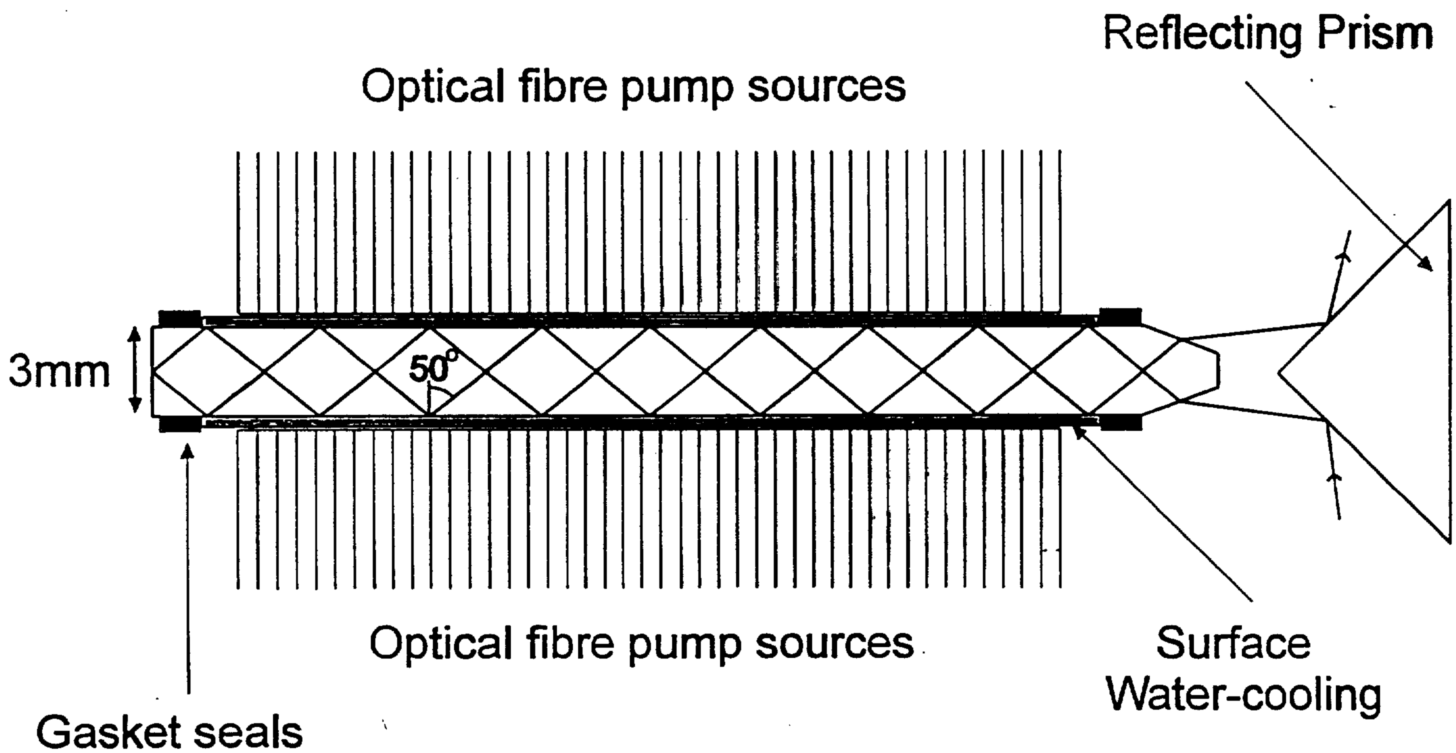
Solution: use a strip unstable resonator (cylindrical geometry) and reduce output coupling. $\bar{R}_{\text{SPHERICAL}} \propto \frac{1}{M^2}$ $\bar{R}_{\text{STRIP}} \propto \frac{1}{M}$ {M = GEOMETRIC MAGNIFICATION}

$\therefore \bar{R}_{STRIP} > \bar{R}_{SPHERICAL}$ BY A FACTOR OF M.

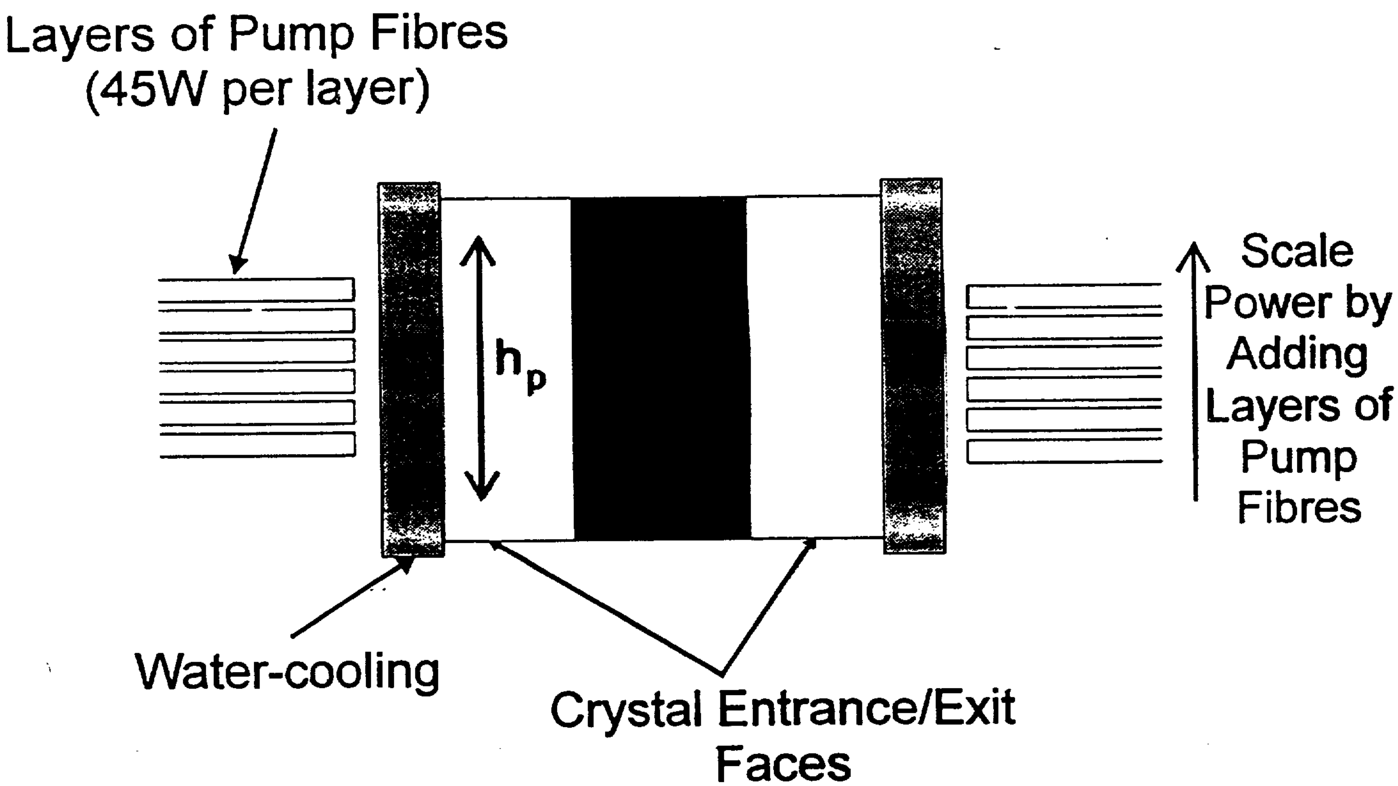
$\longrightarrow$ SIGNIFICANT ADVANTAGE FOR LOW GAIN SYSTEMS SUCH AS CW Nd:YAG

<u>IMPORTANT</u>: MODE DISCRIMINATION PROPERTIES OF UNSTABLE RESONATOR NOT DEGRADED BY USING THE LOWER LOSS STRIP UNSTABLE RESONATOR.

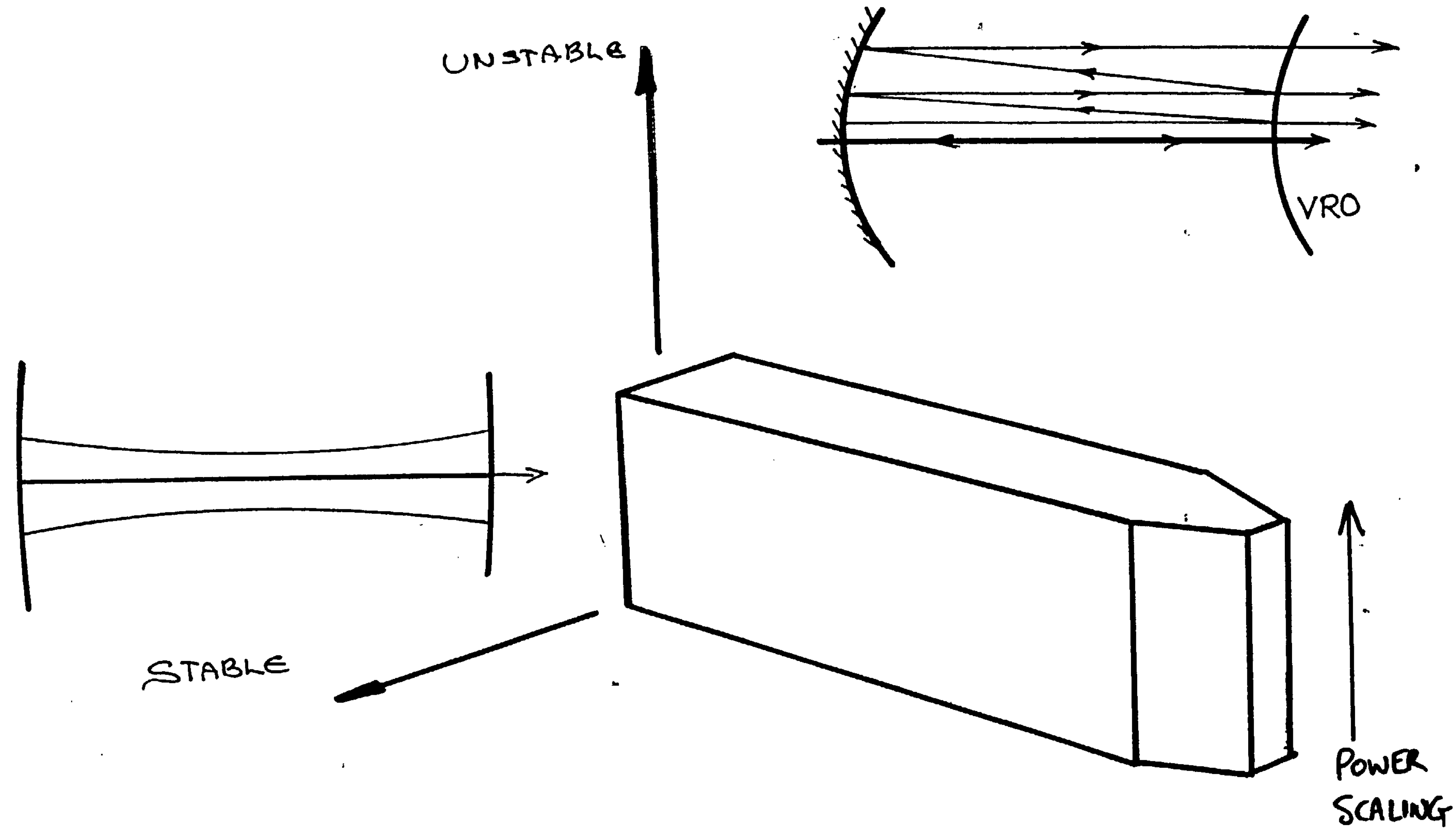
Top View of Laser Slab



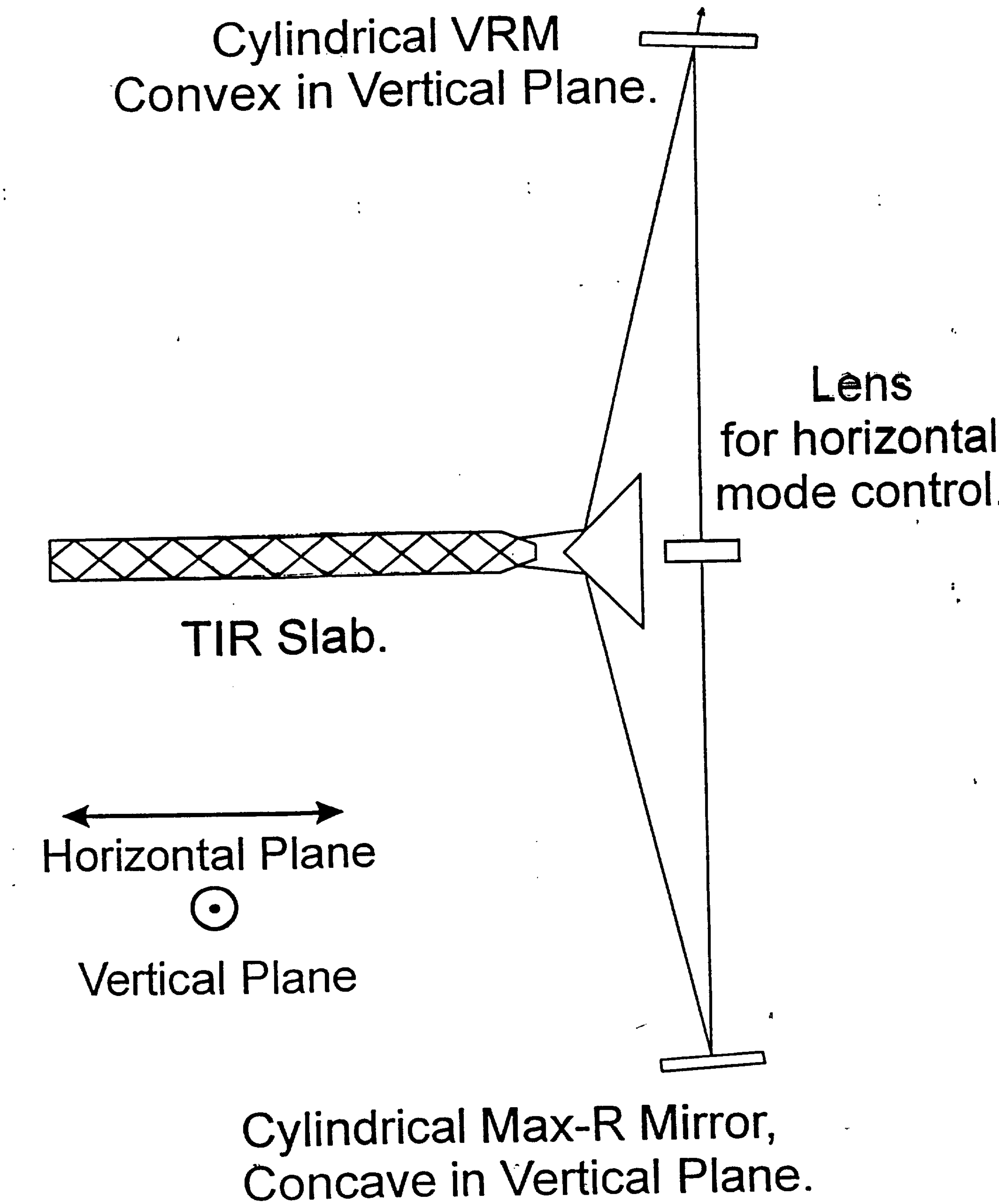
End View of Laser Slab



- SCALE POWER IN VERTICAL DIRECTION.
- UNSTABLE RESONATOR IN VERTICAL PLANE.
- STABLE RESONATOR IN HORIZONTAL PLANE.


UNSTABLE
VRO
STABLE
POWER
SCALING

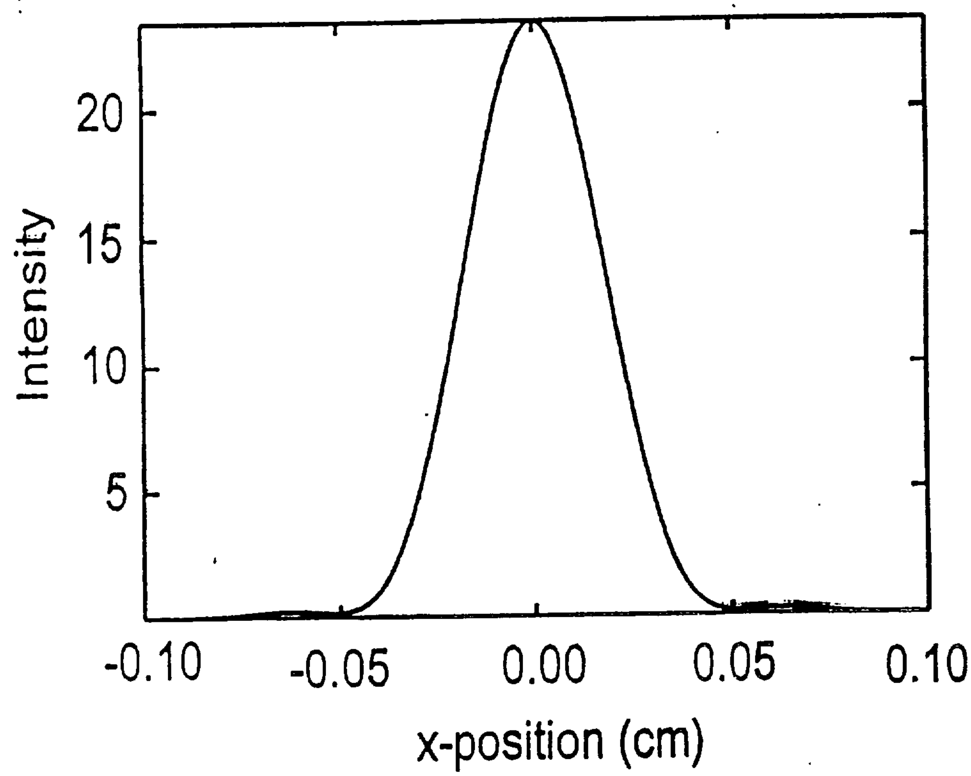
Laser Cavity Configuration



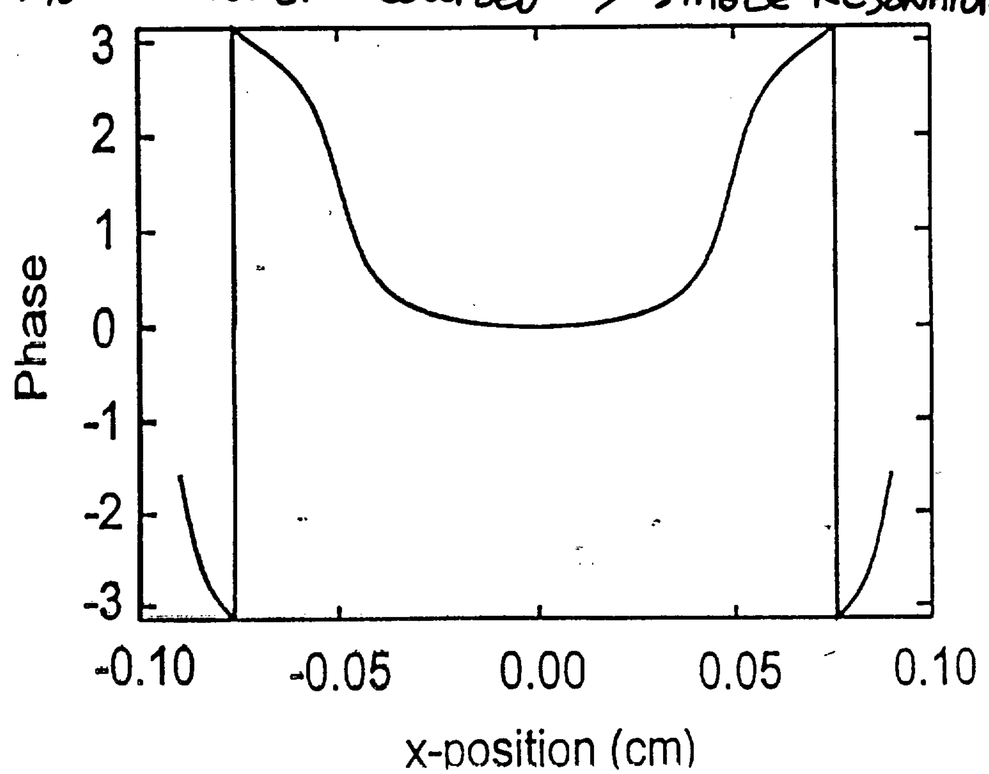
List of Parameters Used in Unstable Resonator Calculations

Total pump power (W)	540
Intra-cavity loss, L	5.6%
Pathlength in pumped region, l_g (mm)	52.2
Small-signal gain, γ_o (mm^{-1})	0.0743
Magnification, M	1.3
Super-Gaussian output coupler order	2
Optimal total output coupling, T_{opt}	0.41
Output coupler effective reflectivity, $\overline{R}$	0.59
Peak reflectivity, R_o	0.77
Output coupler characteristic half width, w_m (mm)	1.12
Near-field characteristic half width (mm)	1.15

Numerically Modelled Far-field Intensity & Phase for Unstable Plane



≈ 98.7% OF POWER COUPLED → STABLE RESONATOR



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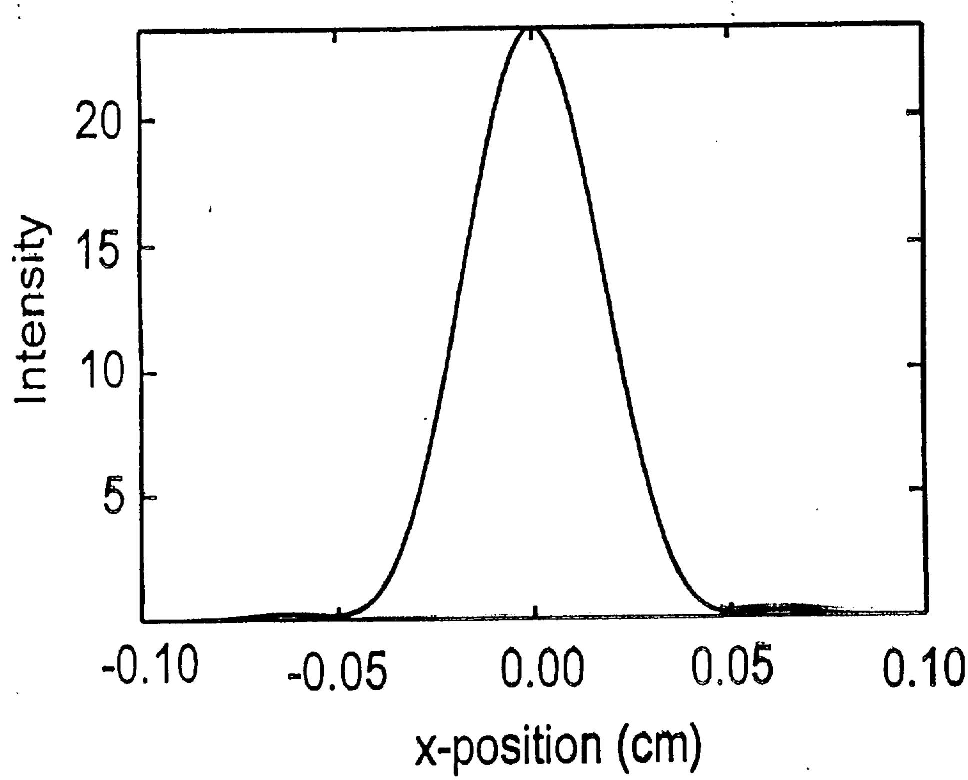

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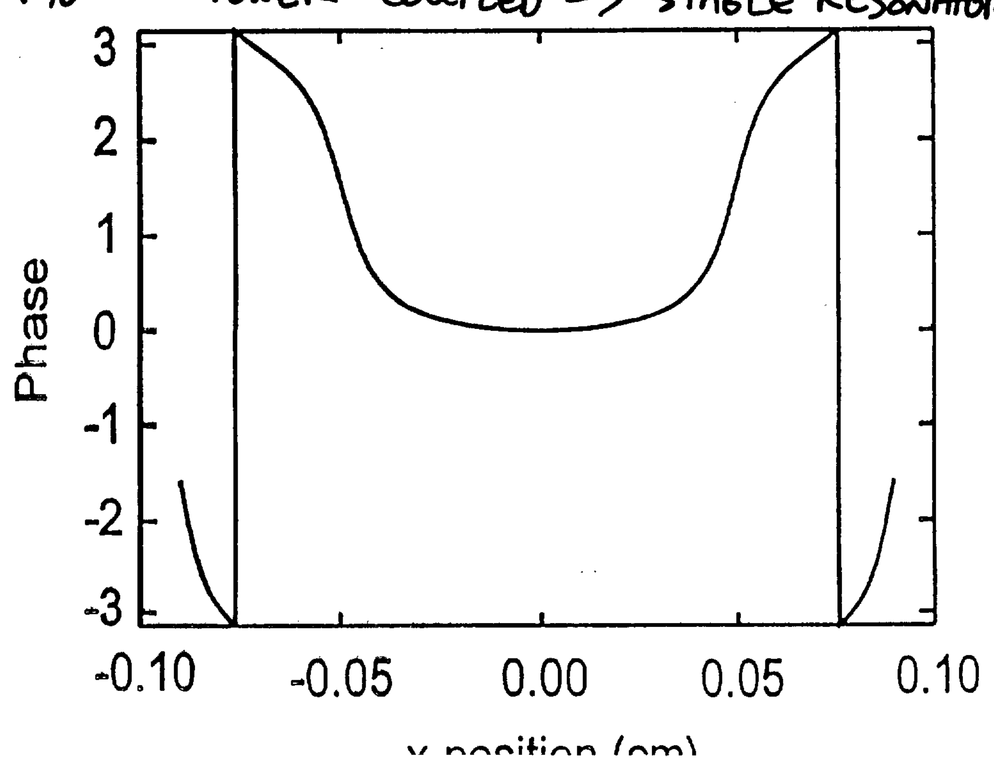
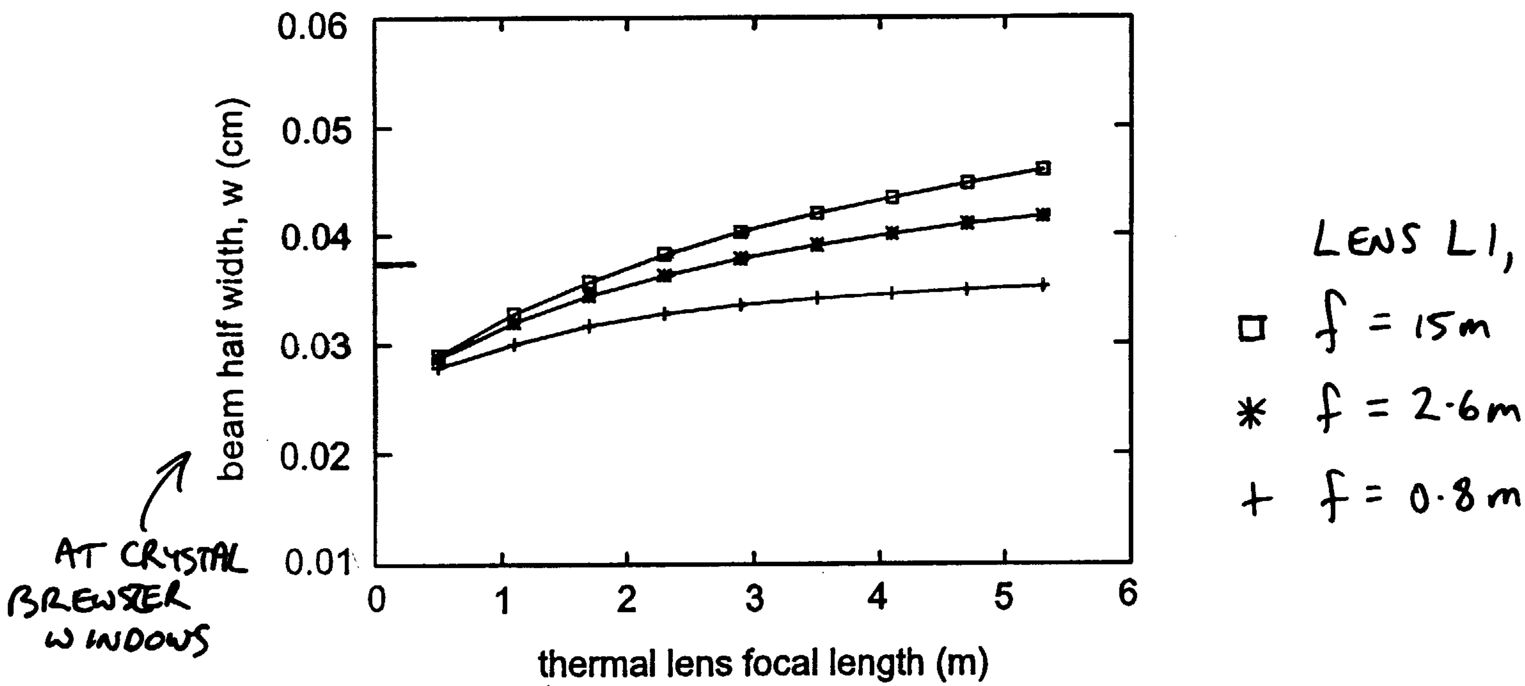
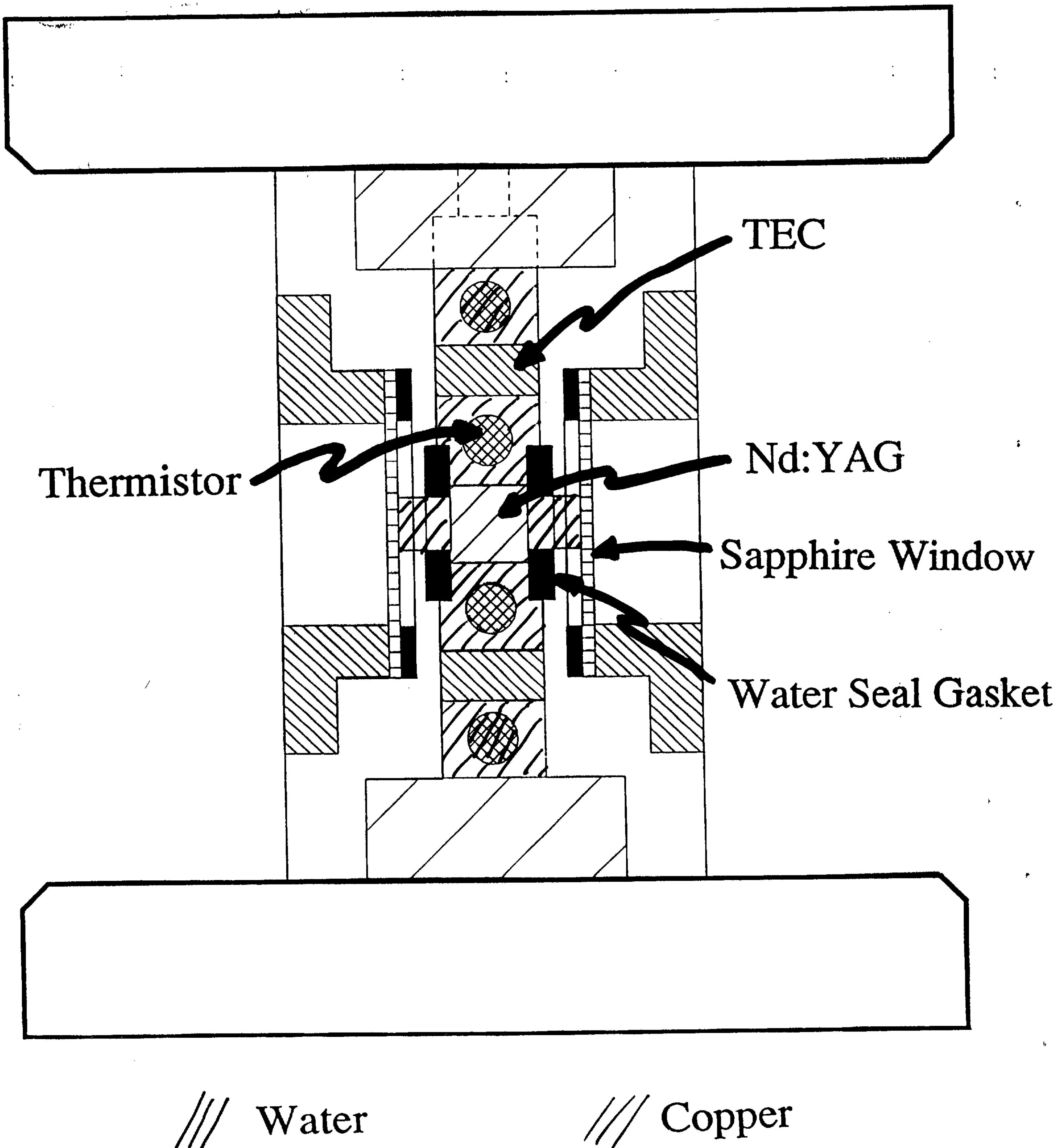


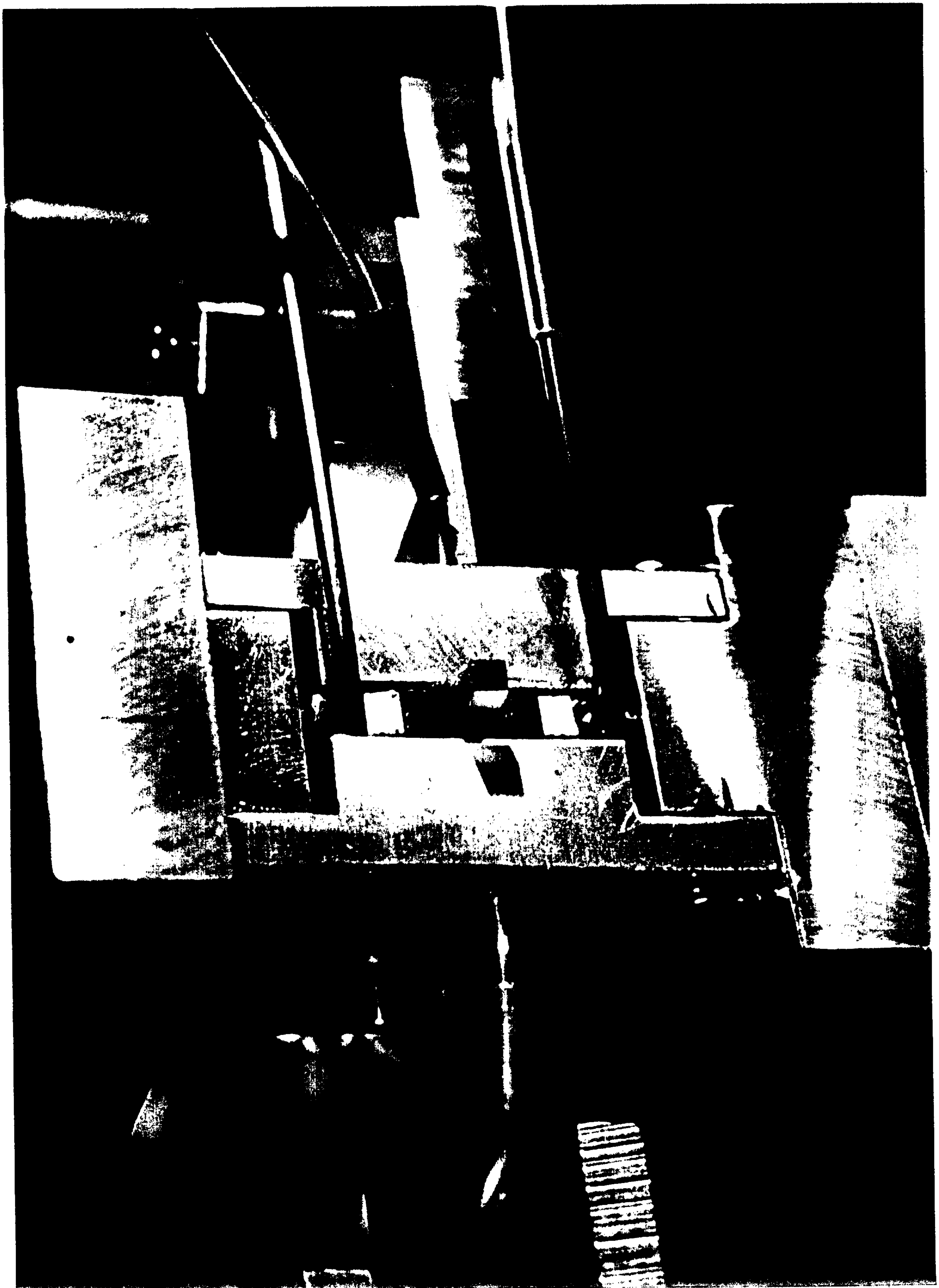
Horizontal (stable) Plane Analysis

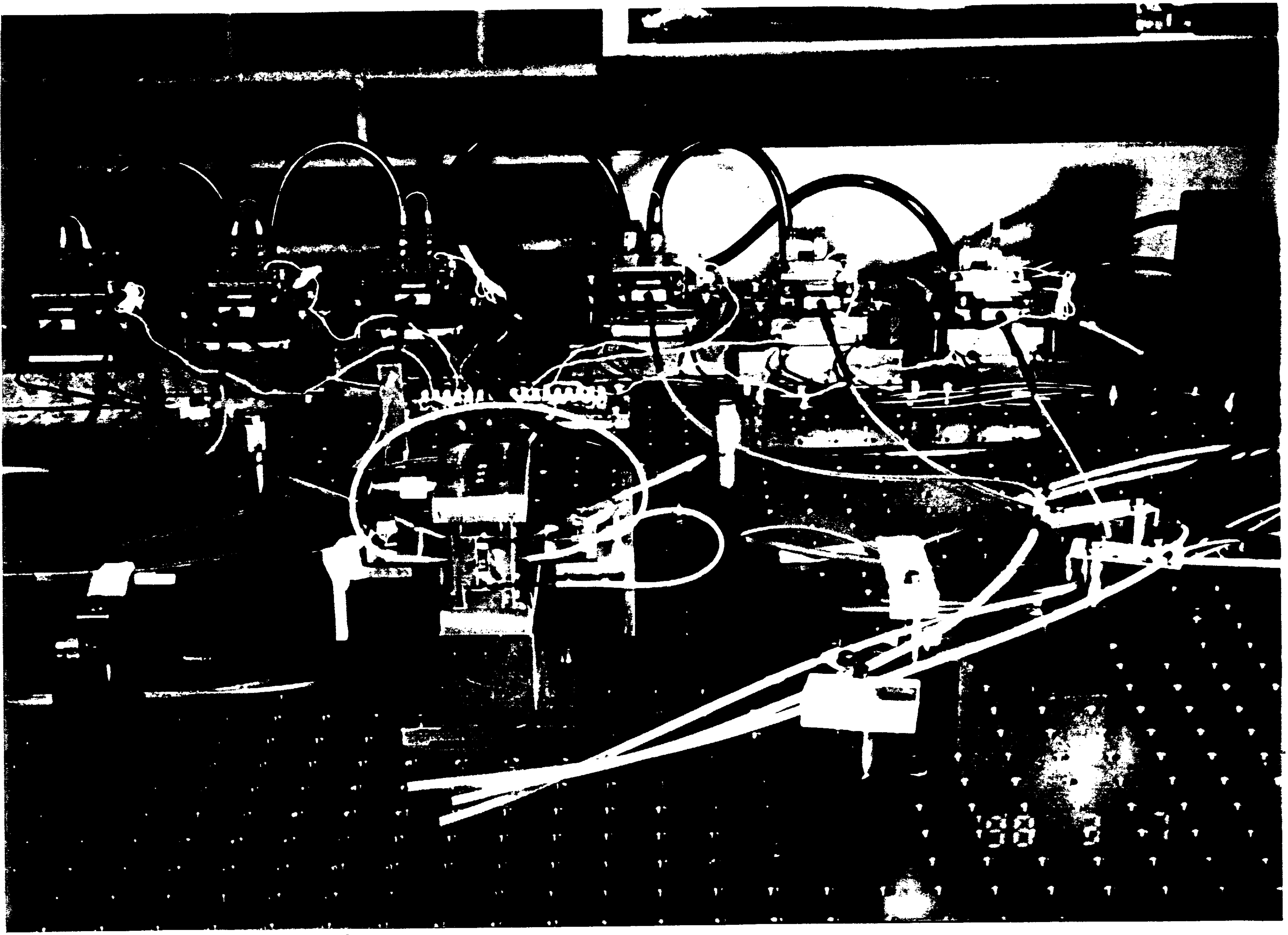


Schematic of Laser Head:

Cross-section



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Experiment Plan

Assemble slab in laser head, with single line-array of optical fibre pump sources.

Characterize:
- small signal gain.
- wavefront distortion.
- vertical and horizontal thermal lensing.
- demonstrate control of temperature gradient in vertical direction. (COMPARE TO FINITE ELEMENT ANALYSIS)

Obtain lasing in this configuration.

Power Scaling Experiments

Add pump fibres in vertical direction.

Investigate:

- transverse mode discrimination.
- beam quality.
- mode matching.

Fibre Options:

- rearrange current optical fibres.
- use additional diode-laser pump fibres from another project.
- suggestions, contributions?

Note 1, Linda Turner, 04/21/98 09:13:32 AM
LIGO-G980049-28-M