LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

- LIGO -

CALIFORNIA INSTITUTE OF TECHNOLOGY

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Argon and Nd:YAG Lasers: Comparative information
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This is an internal working note of the LIGO Project

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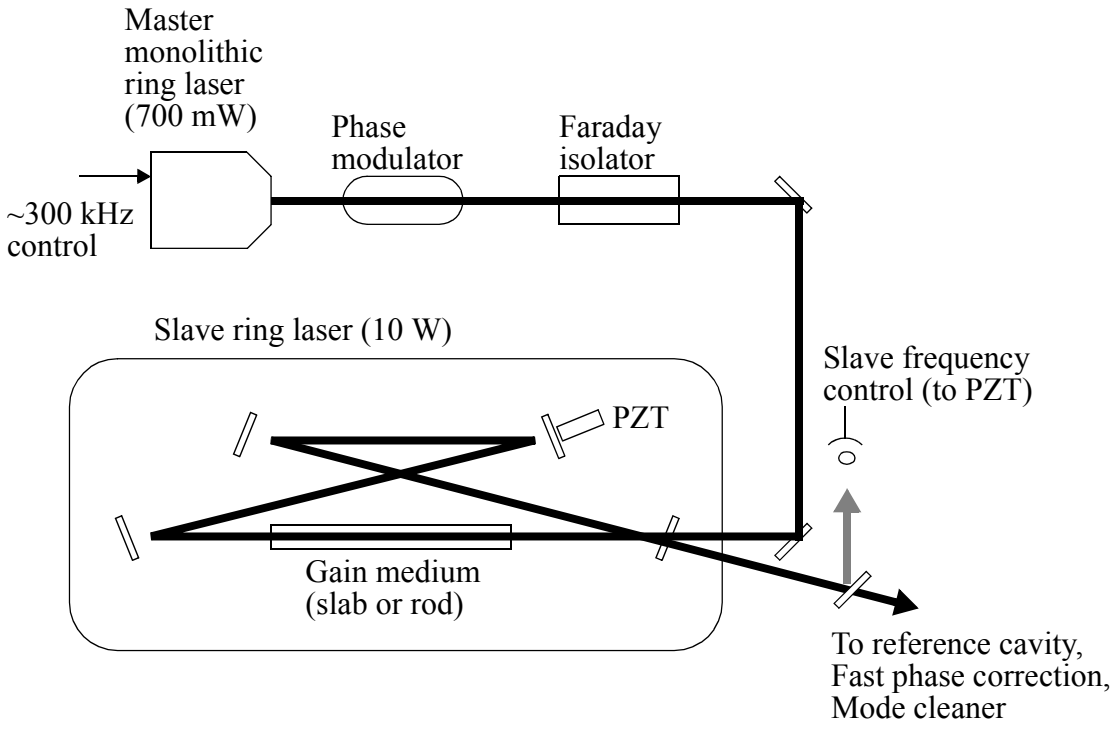
Nd:YAG Technical ‘high points’

Recapitulation of significant differences:

- layout of laser configuration
- summary tables
- R&D effort
- status of other GW/laser groups



Laser Technical Summary

parameter/part	Nd:YAG Merit/*Demerit*	Argon Merit/*Demerit*
power	initial power available, future power assured (20-47 W now) *~2x power required for given sensitivity*	initial power available; *no further increases probable*
efficiency	several 10^{-2}	10^{-4}
mean time before failure	10,000 MTBF (commercial specification) 10-20,000 MTBF (Byer experience)	8000 MTBF (commercial specification) ~2000 MTBF (LIGO experience)
failure mode	~20% reduction in power	*no light*
raw frequency noise, 90 Hz	10^2 Hz$/\sqrt{\text{Hz}}$	10^4 Hz$/\sqrt{\text{Hz}}$
raw intensity noise, 90 Hz	10^{-6} $\delta I/I$ $1/\sqrt{\text{Hz}}$	10^{-5} $\delta I/I$ $1/\sqrt{\text{Hz}}$
raw intensity noise meets ~10 mW shot noise	3 MHz	~5 MHz
beam jitter	not yet characterized; reported to be small (comparable to Argon?)	characterized
engineering status	*~$1M+ 1 year development*	ready
future development	growing market	*static to declining market*

Modulator Technical Summary

parameter/part	Nd:YAG Merit/*Demerit*	Argon Merit/*Demerit*
power handling	to 20 watts	to 5 watts
sensitivity	210 volts/π, 1.06 μm	1000 volts/π, 514 nm
frequency range	to 100 MHz	to 60 MHz (in pairs)
engineering status	commercial item	commercial item

Core Optics Technical Summary

parameter/part	Nd:YAG Merit/*Demerit*	Argon Merit/*Demerit*
mirror size	*back mirror >27 cm*	<25 cm
figure requirements (sample requirement)	Argon * $\sqrt{2}$ $=\lambda_{514}/424$	$\lambda_{514}/600$
required coating uniformity (random errors)	0.1%	0.1%
substrate scatter	1-2 ppm/cm	*10-20 ppm/cm*
substrate absorption	1-2 ppm/cm	1-2 ppm/cm
substrate homogeneity	same to 2x better	---
coating absorption+scatter	6 ppm	~20 ppm (1.5 reported)
metrology	commercial	*special interferometer must be fabricated*
baffle backscatter (SS)	2x smaller	
baffle reflectivity (SS)	*2x larger*	
thermal focussing	same	
contamination	*no experience*	
FFT performance estimate	~10% better	

Suspension Technical Summary

parameter/part	Nd:YAG Merit/*Demerit*	Argon Merit/*Demerit*
end FP mirror	*possible additional design type required*	

Photodetector Technical Summary

parameter/part	InGaAs Merit/*Demerit*	Si (Argon or YAG) Merit/*Demerit*
power handling	150 mA	*15 mA*
quantum efficiency	80-90%	60-70%
surface diameter	*0.5-2 mm*	10 mm or greater
spatial non-uniformity	TBD	$<10^{-3}$
capacitance	low	30 pf/15pf
engineering status	*in development*	commercial

FFT Optics model results for 1.06μm

Parameter	Nd:YAG	Argon
Laser wavelength	1.06 μm	532 nm
Mirror radii: recycling, flats	11.5 cm	12.5 cm
beamsplitter	9.9 cm	12.5 cm
FP back mirrors	14.0 cm	12.5 cm
Laser power (at recycling mirror)	5 W	2.5 W
Assumed loss/bounce on all mirrors	100 ppm	100 ppm
Optimum recycling gain	34	31
Contrast defect (1-C)~ $2(I_{min}/I_{max})$	3×10^{-4}	1.3×10^{-3}
Optimum modulation	0.34	0.47
Photodetector power	260 mW	240 mW
h (below cavity pole frequency)	$5.7\times10^{-24}/(\sqrt{\text{Hz}})$	$6.2\times10^{-24}/(\sqrt{\text{Hz}})$

R&D Activities

R&D goals for Nd:YAG work:

- verify laser, mirror, etc. performance
- integration issues
- gain familiarity with infrared light
- (~500 mW as useful as 10 W for most tests)

Phase Noise Interferometer:

- repeat performance test as for Argon
- probably follows de-bugging with Argon; streamlines path
- could be a mid-stream switch
- guess of 9 months if at end, and preparations made

40 m Interferometer:

- test of integration (as for PSL)
- put in test plan ‘when convenient’ (displaces/delays other work)
- also roughly 9 months

OTF:

- tests of mirrors
- contamination
- frequency stabilization

Activity of other groups

Stanford

- basic master laser design (NPRO)
- various high-power diode-pumped designs
- interest in LIGO as User Group, Helper

VIRGO

- delivery of 10 W slave in August
- integration with master in October
- interested in collaboration (serial #2)

GEO

- independent master design
- 20 W rod demonstrated
- frequency and power stabilization underway

TAMA

- novel rod at 26 W
- excellent frequency stabilization effort
- low-loss mirrors demonstrated

AIGO

- no specifics

Summary of summary

Second look at Nd:YAG and 1064 nm:

- laser looks close to ready for our needs
- other bits and pieces (modulators, photodetectors) ok
- optics shows fewer advantages for 1064 nm than anticipated
  - Ar mirrors improving
  - both better than initial LIGO needs
- several disadvantages (baffling, mirror size, lack of familiarity)
- still looks like a sure path for enhanced LIGO (2x to 10x power)