LABORATORY FOR SCIENCE
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MODEL 260

ULTRA-STABLE LASER

General Performance:

The Model 260 will provide the user with a reliable and stable single frequency source of substantially greater power output than heretofore available commercially. The plasma tubes are preselected to provide an initial single frequency power output of 3 mw or more, and mid-life values often exceed 3.5 mw. When used as a frequency stabilized source without a polarizer for single mode selection, the power output is typically between 6 to 7 mw. In the absence of retroreflection, the Model 260 will provide a source of excellent frequency stability, both short and long term. However, the frequency stability of this type of laser is quite sensitive to retroreflection, especially when used in the polarized single frequency output mode. It should be noted that this latter mode will exhibit an amplitude modulation of some 2.5% peak-to-peak at a frequency of several hundred kiloHerz. (The exact frequency is fixed and determined by the particular laser tube employed.) Further, in polarized single frequency operation there is also a small amount of power, typically less than 2% of the total, located in axial modes ± 860 MHz from line center. Programming the laser to operate other than at line center will significantly increase the sum total power in these satellite modes.

Theory of Operation:

In a laser with three TEM_{oo} modes there will be two primary beat frequencies corresponding to the difference frequencies between the central mode and each of the modes on either side of center. These two beat frequencies, typically in the range of 400 to 500 MHz, will in general not be exactly the same because the frequency pulling effects on each mode will vary with the differing slopes at the respective operating points on the Doppler gain curve. The difference between these two beat frequencies will yield a third or intercombinational beat frequency typically in the range of 100 kHz. In an integral end mirror tube, where the alternate modes are orthogonally polarized, the intercombinational beat frequency will not be zero even when the central mode is at line center because of the birefringence of the mirrors. In the Model 260, the laser tube is preselected not only for power but also for an appropriate range in the intercombinational beat frequency. The median frequency is then tightly phase locked to the frequency of a crystal controlled frequency synthesizer. This tight phase lock accounts for the high degree of short and long term stability achieved with the Model 260. In addition the use of this digital control system makes it possible to slave the Model 260 to a reference laser, such as the Model 220, to improve its frequency stability in the presence of retroreflection. We have found that the orientation and degree of birefringence in the chosen laser tubes remain remarkably constant throughout the life of the laser tube, and readjustment of the plane of polarization or the lock-frequency setting is rarely necessary to maintain a quality single frequency output.

Other Features:

The Model 260 employs virtually the same phase locking architecture that is used in the Model 220. The frequency synthesizer provides a three decade modulus set by digital switches on the side of the Power Control Unit, and very readily permits the central output mode to be locked on line center. Additional preset binary stages allow for the variability in different plasma tubes. The Mode Options Plug, located on the underside of the Power Control Unit facilitates non-standard modes of operation.

As with other members of the Model 200 Series, headphones are supplied as a standard accessory to help the user minimize the problem of retroreflection. Where some loss in long term frequency stability is acceptable, the convenience of a beam shutter equipped with a high efficiency cube polarizer and Brewster angle absorber is available as an optional accessory.

Application Hints:

If the full frequency stability of the Model 260 is to be realized, the associated optical system should be configured to reduce the problem of retroreflection and/or back scattering to an absolute minimum. Whenever possible, one should work at a distance to minimize back scattering and to allow space for the complete absorption of any specular reflections (by means for example with the Model 211 Black Etalon). Since back scattering from an internally mounted cube polarizer may degrade the frequency stability by as much as a factor of ten from the indicated specifications, we also offer a 'reduced drift' version of this laser. With this option (and an external polarizer set to operate at a distance), we include additional components to reduce the drift down to 50 kHz/day. For the purpose of defining the correct axis orientation, a simple HN-32 polarizer is supplied.

In the case of interferometers, designs of the Mach-Zender type, or any of the corner cube variants of the Michelson type, are much to be preferred because the interfering beams cannot retrace their paths back to the laser except by reflection or back-scattering from the detector. Problems of this latter type can be solved by tilting the PIN diode detector by at least half the convergence angle of the photodiode focussing lens, having it slightly inside the focal point of the lens, and using a circular polarizer in front of the lens.

Where direct retroreflection is unavoidable, proper isolation will require a high-quality calcite polarizer that will provide an extinction ratio of at least 10^{-5}, and a V-coated* quarter waveplate very accurately oriented both as to tilt and azimuthal angle. Where intervening optical components alter the state of polarization of the returning beam so that it is no longer perfectly circular, it may be necessary to intoduce appropriate compensating plates.

Another technique to reduce the problem of retroreflection that can often be used to good advantage, especially when a component scatters the polarization, is to use the unpolarized beam and position potentially troublesome components at a "servo system nodal point" i.e. at an integral number of plasma tube cavity lengths from the output mirror. The high intensity vertically polarized central mode is then selected out before the detector to provide single frequency performance.

In each case the headphones and touch test can be used as a diagnostic and corrective technique to arrive at in situ adjustments that will assure the optimum system performance.

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* For that fraction of the light undergoing a zig-zag double internal reflection, there is is an additional half wave retardation that permits retroreflection of this fraction to pass directly back through the polarizer. The low reflectivity provided by a 6328 V-coat on the waveplate surfaces is therefore highly desirable.

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Specifications:

Frequency of emitted light (THz)	473.612 200*
Frequency control range (MHz)	±15
Spatial mode structure	TEM_{00}
Beam diameter $\langle 1/e^2 \rangle$ (mm)	0.8 0.37
Beam divergence angle (mrad)	1.0 2.2
Method of stabilization	Intercombinational beat phase locked to Xtal
Unpolarized axial mode structure	triple frequency
Axial mode spacing (MHz)	435
Total power output (mW)	6.0
Amplitude noise (% rms):	
10 Hz - 100 kHz	< 0.02
1 - 2 MHz	< 0.02
Polarized axial mode structure	single frequency
Power output (mW, w/cube polarizer)	3.0 - 4.0
Amplitude noise (% rms):	
10 Hz - 100 kHz	< 0.02
1 - 2 MHz	< 0.1
Amplitude modulation (% rms)	< 1
Frequency of ampl. mod. (kHz)	200 - 1000
Frequency stability (kHz):	
1 sec	< 10
1 min	< 10
1 hour	< 50
1 day	< 200
Warm-up time (min):	
for stable operation	35
for rated specifications	90
Laser head operating temperature (°C)	40
Environmental temperature range (°C):	
for normal operation	22 ± 4
for limited stability (± 1°C)	5 - 17, 27 - 33
for storage	5 - 45
Cube polarizer	Yes
Reduced drift option (HN-32 Pol. <T=0.7>)	Yes
Plasma tube options	No
Accessories available	Yes
Laser head dimensions (in/cm)	3x3x12/7.5x7.5x43
Laser head weight (lb/kg)	7.5/3.4
Power control unit dimensions (in/cm)	6x3x7.5/15x7.5x19
Power control unit weight (lb/kg)	6.2/2.8
Operating voltage (V)	115 or 230 (spec.)
Power consumption (W)	70
B.R.H. Class IIIb compliance	Yes
Accessories included	Headphones

* Final zero not significant.