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Acousto Optic Mode Lockers

Features/Applications

- Low Power Lasers
- MHz/GHz RF Frequency Modulation Rate
- Analog Light Intensity Modulation
- Digital Switching On/Off
- Air or Thermoelectrically cooled
- Low Cost

The Output from a laser is usually comprised of a number of frequencies corresponding to the longitudinal mode frequencies of the resonant cavity. These frequencies are given by

$$(1)v_{mnq} = \frac{c}{2L}\left[\frac{m+n+1}{p}\arccos\sqrt{\left(1-\frac{L}{r_1}\right)\left(1-\frac{L}{r_2}\right)}\right]$$

where c represents the speed of light, L represents the optical length of the resonant cavity, and r_1 and r_2 represents the curvature radii of the two cavity mirrors. The transverse mode indices are given by m and n, while q represents the longitudinal mode index. The values for m, n, and q indicate the number of transverse and axial nodal points (i.e., the number of points where E= 0) for the optical field within the resonant cavity. Clearly, from Eq. (1), the longitudinal mode frequencies v_{mnq} are equally spaced for a parallel-planes cavity ($r_1 = r_2 = \infty$, as frequently used in a solid-state laser), and for the lowest-order transverse mode (m = n = 0), the preferred operating mode since no nodal points exist in the cross-sectional plane. The frequency space v_0 between adjacent longitudinal modes is given by

$$(2)v_0 = \frac{c}{2L}$$

For example, if the optical length of the cavity is L=1.5 m, we have $v_0 = 3\text{x}\ 10^8/(2\ \text{x}\ 1.5) = 100$ MHz.

The actual number of longitudinal modes N which may exists in a specific laser beam is dictated by the number of longitudinal modes within the gain profile for which the gain exceeds the laser oscillation threshold. Normally, the relative phases of the various longitudinal modes are random, therefore the total intensity of the laser output is given by an intensity summation of the existing modes. This summation approximately equals N times the intensity of a single longitudinal mode. The mode- locking technique is actually a phase-locking process, connecting the various longitudinal modes by fixing the relative phase differences among them. There are three conclusions that can be drawn from a Fourier analysis of this scheme. First, given a superposition of this scheme. First, given a superposition of signals separated in frequency space by v_0 (with fixed relative phase differences), the result will be an optical pulse train. The period T of this pulse sequence will be

$$(3)T = \frac{1}{v_0} = \frac{2L}{c}$$

For example, T=10 ns when v_0=100 MHz. Second, the width Δt of each light pulse is inversely proportional to the total number N of longitudinal modes locked and is approximately equal to

$$(4)\Delta t \approx \frac{1}{N}T$$

If N= 10^4 and T = 10 ns, then Δt = 1ps. Third, the amplitude E of each light pulse is proportional to the total number N of longitudinal modes locked and is aproximately equal to $E = NE_0$, where E_0 is the amplitude of an individual longitudinal mode. As a result, the intensity I of each light pulse is given by

$$(5) I = N^2 I_0 = NI$$

Where I_0 a E_0^2 is the intensity of a single longitudinal mode and $I = NI_0$ is the intensity with no mode-locking. According Eqs. (4.) and (5.), the larger the value of N the better the mode-locking. To maximize N, the gain profile should be broadened and the laser oscillation threshold reduced to minimum.

The basic method of mode-locking is to induce a periodic cavity loss with a period T given by Eq. (3). This periodic cavity loss serves to filter the optical pulse train in a manner equivalent to locking the phases of the various longitudinal modes. A particularly sophisticated means of introducing a periodic cavity loss is through the use of an acoustic standing wave AO device. For standing wave AO device, there is no device, there is no acoustic absorber opposite the terminal surface. Rather, the opposite surface parallels the terminal surface (the surface on which the transducer is attached), so as to reflect the incident acoustic wave. The resulting acoustic wave has a frequency twice that of the original acoustic wave. If the original acoustic frequency is f_0, the strain at the antinodal points (halfway between the adjacent nodal points) in the AO medium will cycle through a maximum and minimum (zero) value at a frequency of $2f_0$. If the frequency of the acoustic wave in a standing wave AO device is given by

$$(6) f_0 = \frac{v_0}{2} = \frac{c}{4L}$$

Then a periodic cavity loss of frequency v_0 is produced and the desired mode-locking is realized. The A-O device operates in the Raman-Nath or Bragg regime with Brewster angle incidence. In order to obtain an acoustic standing wave, the two surfaces perpendicular to the acoustic wave propagation direction must be exactly parallel. In addition, the distance W between these surfaces should equal an integer multiple of /2. Since the distance separating these surfaces usually approximates 10 mm while is on the order of 10 µm, it is nearly impossible to meet this condition in advance. Instead, the driving source frequency f_0 should be variable so that a standing wave can be established within the AO medium. By adjusting the position of the cavity mirrors, it is possible to get the proper value $v_0=2f_0$.*

***** Jieping Xu and Robert Stroud, Acousto-Opitc Devices: Principles, Design, and Applications., 1992.

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IR Mode Lockers

	AOML For Nd: Yag Laser	AOML For Ti: Sapphire Laser
	FSML-50-20-BR-1064	**FSML-44-20-BR-800***
Substrate:	Fused Silica (Uncoated)	Fused Silica (Uncoated)
Laser Wavelength:	Brewster Cut optimized for horizontal polarization at 1064 nm	Brewster Cut optimized horizontal polarization at 800 nm
Active Aperture:	3 x 3 mm	3 x 3 mm
Carrier Frequency:	50 MHz	44 MHz
Modulation Rate:	Bandwidth (3dB):	Optical Transmission:
Resonant Diffraction Efficiency:		
@34 MHz	50%	60%
@44 MHz	38%	83%
@54 MHz	33%	75%
Non-Resonant Diffraction Efficiency:		
@34 MHz	15%	30%
@44 MHz	22%	40%
@54 MHz	17%	30%
Acoustic Velocity:		
Wave Front Distortion:	$\lambda/10$	$\lambda/10$
Input Impedance:	50 ohms	
Maximum Electric Input Power:	5 - 7 Watts	5 - 7 Watts
V.S.W.R.:	2.1:1	2.1:1
Case Type:	#130	#130

** B.E. Lemoff and C.P. Barty, Generation of high-peak-power 20-fs pulses from a regeneratively initiated, self-mode-locked Ti:Sapphire laser, Optics Letters, Vol. 17, No. 19, pp. 1367-1369, (1992).*

The above data was performed at a specified wavelength. Other wavelengths (spectral ranges) between 600 to 1000 nm or Broadband AR Coating and RF Frequency Ranges are available upon request.

Variable Frequency Drivers

(For Models: FSML-50-20, FSML-44-20)

	VFE-50-20-DSP1kHz-F7-X	**VFE-44-20-DSP1kHz-F7-X**
Frequency Range:	50 ± 10	44 ± 10
Frequency Resolution:	1 kHz	1 kHz
Harmonic Content :	≤ - 20 dBc	≤ - 20 dBc
Stability:	0.5 ppm after 15 minute warm-up, temperature stabilized Crystal Oscillator referenced	
Output Power:	5 - 7 Watts manually adjustable via a front panel. Power is optimized for peak efficiency with supplied A-O device.	
Operating Power:	100 VAC +/-10%, 50-60Hz, 50W max.	
Standard Features:	-High Stability Temperature Controlled Oscillator	-Front panel frequency control (1 KHz step)via thumbwell switches
Enclosure:	The unit will be packaged in forced air cooled a 7.5 in wide by 3.5 in high by 8.75 in deep instrument case. The internal components are fan forced air cooled. Size is exclusive of connectors. A detachable AC line cord is provided.	
Environmental:	Nominal Laboratory Conditions: Max temperature 0-50 deg C ambient; the unit is not sealed against moisture or condensing humidity.	
Option"X":	Return voltage readout for adjustment to a resonant frequency	

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IR Mode Lockers

AOML for:	Nd:Yag Laser	Ti:Sapphire Laser	Nd:Yag Laser
	FSML-80-20-BR-1064	**FSML-125-30-BR-800**	**FSML-125-30-BR-1060**
Substrate:	Fused Silica	Fused Silica	Fused Silica
Laser Wavelength:	Brewster Cut optimized for horizontal polarization at		
	1064 nm	800 nm	1060 nm
Active Aperture:	3 x 3 mm	3 x 3 mm	3 x 3 mm
Carrier Frequency:	80 MHz	125 MHz	125 MHz
Modulation Rate:	160 MHz	250 MHz	250 MHz
Bandwidth (3dB):	20 MHz	30 MHz	30 MHz
Optical Transmission:	99.7%	99.7%	99.7%
Modulation Depth at resonant Frequency:	@80 MHz 60%	@125 MHz 50%	@125 MHz 30%
Modulation Depth at Non-Resonant frequency:	@80 MHz 11%	@125 MHz 5%	@125 MHz 3%
Acoustic Velocity:	5.96E+3 km/sec	5.96E+3 km/sec	5.96E+3 km/sec
Wave Front Distortion:	$\lambda/10$	$\lambda/10$	$\lambda/10$
Maximum Electric Input Power:	5 - 7 Watts	5 - 7 Watts	5 - 7 Watts
Input Impedance:	50 ohms	50 ohms	50 ohms
V.S.W.R.:	2.1:1	2.1:1	2.1:1
Case Type	# 140	# 140	# 140

Variable Frequency Drivers

(For Models: FSML-80-20, FSML-125-30)

	VFE-80-20-DSP1kHz-F7-X	**VFE-125-30-DSP1kHz-F7-X**
Frequency Range:	80 ± 10	125 ± 10
Frequency Resolution:	1 kHz	1 kHz
Harmonic Content :	≤ - 20 dBc	≤ - 20 dBc
Stability:	0.5 ppm after 15 minute warm-up, temperature stabilized Crystal Oscillator referenced	
Output Power:	5 - 7 Watts manually adjustable via a front panel. Power is optimized for peak efficiency with supplied A-O device.	
Operating Power:	100 VAC +/-10%, 50-60Hz, 50W max.	
Standard Features:	-High Stability Temperature Controlled Oscillator	-Front panel frequency control (1 KHz step) via thumbwell switches
Enclosure:	The unit will be packaged in forced air cooled a 7.5 in wide by 3.5 in high by 8.75 in deep instrument case. The internal components are fan forced air cooled. Size is exclusive of connectors. A detachable AC line cord is provided.	
Environmental:	Nominal Laboratory Conditions: Max temperature 0- 50 deg C ambient; the unit is not sealed against moisture or condensing humidity.	
Option”X”:	Return voltage readout for adjustment to a resonant frequency	