High-Beam-Quality Sealed-Off Laser System Oscillating in Middle Infrared Spectral Range on Strontium Atomic Transitions for Application in Material Science and Medicine

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INTRODUCTION

By means of a free electron laser (FEL) with variable wavelength in the middle infrared (MIR) spectral range between 3 and 20 μm, it has been found that the laser radiation at 6.45 μm is the most effective tool for soft tissue and bone ablation with minimal thermal damage and smear layer. Application of FEL in clinical systems for precise laser ablation of soft tissue and bones is inhibited by its size, cost, and considerable overheads. Multiwatt high-beam-quality strontium (Sr) atom laser with Sr, strontium dibromide ($SrBr_2$) and strontium dichloride ($SrCl_2$) vapor oscillating at 6.45-μm laser line could be successfully applied instead of FEL.

AIM

To develop Master Oscillator – Powerful Amplifier (MOPA) oscillating in MIR spectral region on Sr atomic and ionic transitions, in which high-beam-quality low-power laser radiation from the oscillator is amplified to the required level of energy laser parameters.

EXPERIMENTAL SETUP

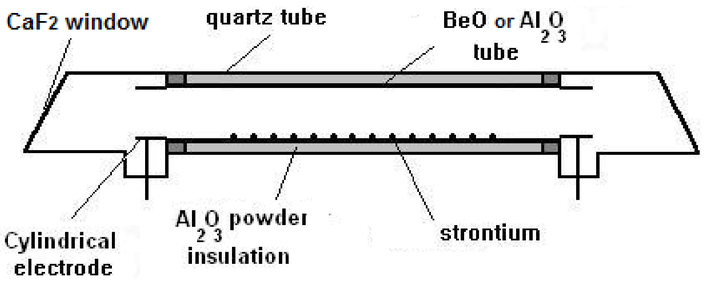

Fig. 1. Schematic diagram of studied laser tubes.

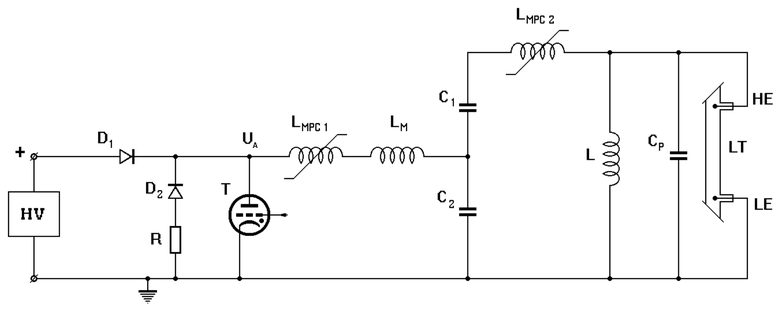

Fig. 2. Schematic diagram of electrical pulsed excitation scheme.

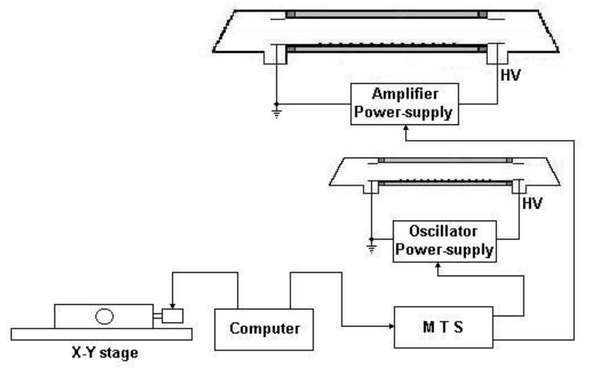

Fig. 3. Schematic diagram of MOPA system excitation and control system.

EXPERIMENTAL RESULTS

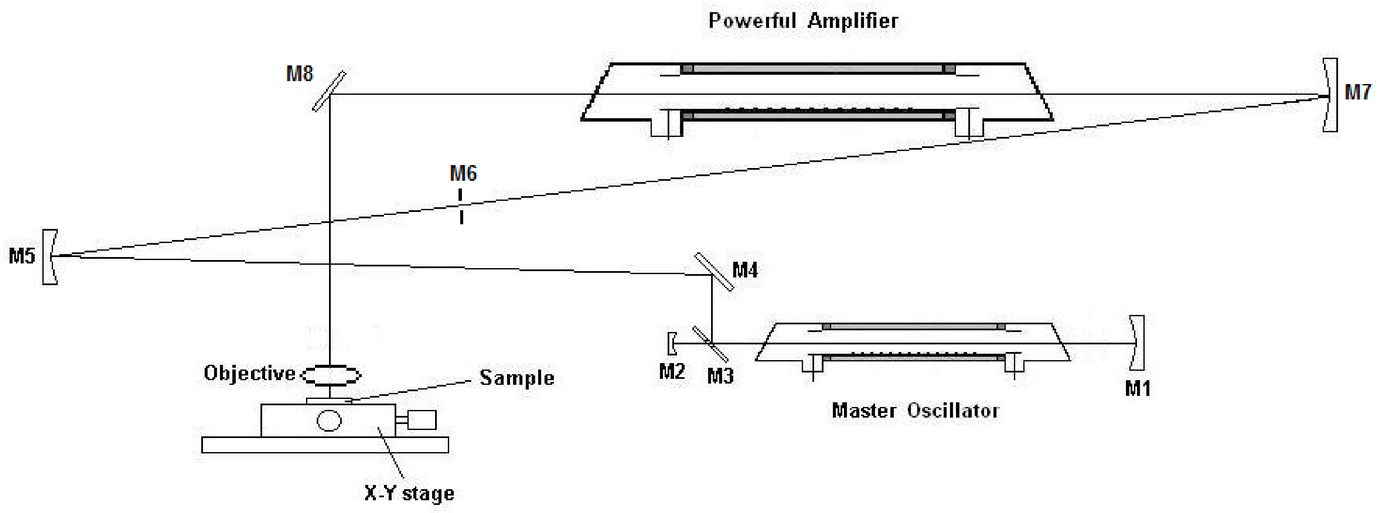

Fig. 4. Schematic optical diagram of MOPA configuration investigated.

Useful formulae

$$M^2 = \frac{\theta}{\theta_{00}} = \frac{\pi}{4\lambda f} Dd \qquad P_S = \frac{1}{\pi f^2}\frac{P_{out}}{\theta^2} \qquad B_M = \frac{P_{out}}{\left(M^2\right)^2}$$

Table I: Parameters of optical elements, namely mirrors, lenses, diaphragms.

Optics	M1	M2	M3		M4	M5	M6	M7	M8	Objective
Focal length (cm)	120	6	∞	Orifice diameter 0.8 mm	∞	50	Orifice diameter 0.5 mm	100	∞	5-50

Table II: d_a – active zone diameter; l_a – active zone length; $p_{He\text{-}Ne}$ – pressure of the buffer gas mixture; C_i – nominal value of the capacitors; U_C – capacitor bank voltage; *prf* – pulse repetition frequency; P_{in} – average output power; P_{out} – average output power; τ_p – laser pulse duration (FWHM); E_p – laser pulse energy; $\theta_{1/2}$ – laser beam divergence.

Single laser tube	$p_{He\text{-}Ne}$ (Torr)	C_1 (nF)	C_2 (nF)	U_C (kV)	*prf* (kHz)	P_{in} (W)	P_{out} (W)	E_p (mJ)	θ (mrad)
Maser Oscillator	90-10	0.6	0.7	6	17	400	1	0.059	0.780
Powerful Amplifier	90-10	0.5	0.6	9	17	755	3	0.176	0.390

CONCLUSIONS

The contribution of the 6.45-μm Sr atom laser line to the total multiline average output power enhances from 75 % with the increase in the operating temperature to 90 % under stationary conditions. The diffraction limited divergence for 11-mm aperture and wavelength of 6.45 μm is 747 μrad. A MO M^2 of 1.044 is measured with a concave mirror with focal distance of 2.40 m at the 6.45-μm laser line, i. e. the MO is diffraction limited. Laser oscillation in the MIR spectral range with average output power of 3 W and laser beam divergence of 390 μrad is also achieved by the MOPA system described in a sealed-off regime. The life time of the PA exceeds 350 hours, while the MO reaches a life time of only 75 hours. Optical-mechanical system for precise micromachining is also developed and investigated.