Active Volume Scaling of Gold Vapor Laser Oscillating in Ultraviolet and Deep Ultraviolet Spectral Ranges

I. K. Kostadinov, K. A. Temelkov, L. T. Popova, S. I. Slaveeva, G. P. Yankov
Metal Vapour Lasers Laboratory, Institute of Solid State Physics, Bulgarian Academy of Sciences
72 Tzarigradsko Chaussee, 1784 Sofia, BULGARIA
E-mail: temelkov@issp.bas.bg

INTRODUCTION

Metal vapor lasers operating on the atomic self-terminating transitions of different chemical elements, such as copper, gold (Au), strontium, lead, iron, etc., are still very promising, because of the possibility to deliver significant average laser power at relatively high efficiency in any spectral range, namely from ultraviolet (UV) to middle infrared ones. Even the average output power of the copper vapor laser (CVL) is still the highest one in the visible spectral diapason so far. Nevertheless, the well-developed UV laser sources, such as excimer lasers and frequency-converted solid state lasers, prevail in the UV spectral range. Unfortunately, the gold vapor laser (GVL) is the only one laser source that operates on the atomic Au self-terminating transition in the UV spectral diapason. The GVLs are less researched and developed in comparison with the CVLs and their various versions, due to the severe difficulties related to the extremely high operating temperature for both atomic Au 627.8- and 312.2-nm lines and the impossibly contradictory gas-discharge conditions for the UV laser line. In Table 1 the highest results obtained at the atomic Au 627.8- and 312.2-nm lines are summarized.

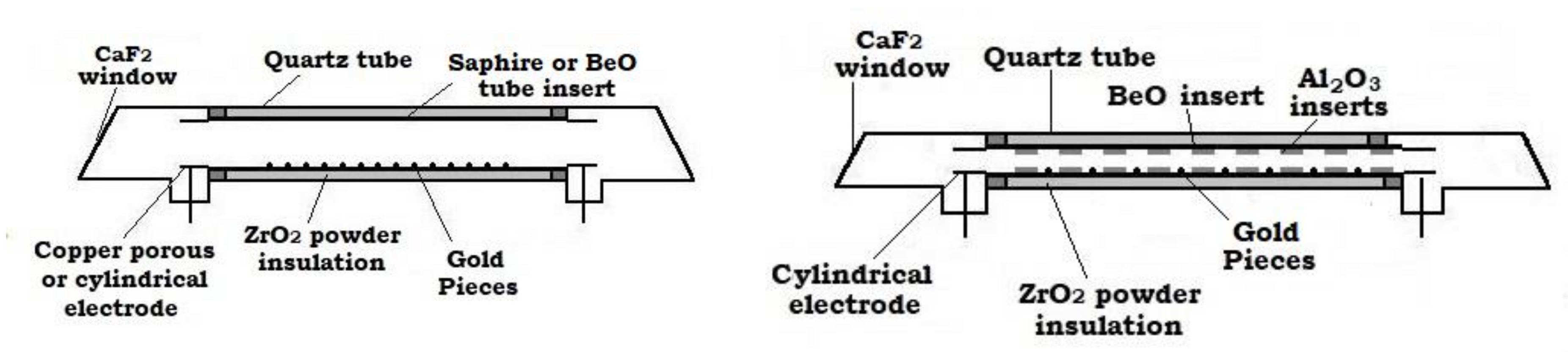
Table 1. Features of the discharge tubes, electrical input parameters and output laser characteristics: d_a – active zone diameter; l_a – active zone length; V_a – active zone volume; ***prf*** – pulse repetition frequency; P_{in} – average electrical power; P_{out} – average output power; $P_{out}^{sp} = P_{out} / V_a$ – specific average laser power; **UC** – unstable cavity.

d_a (mm)	l_a (cm)	V_a (cm^3)	*prf* (kHz)	P_{in} (kW)	P_{out} (W)		P_{out}^{sp} (mW/cm^3)		Reference
					312.2 nm	627.8 nm	312.2 nm	627.8 nm	
55	100	2376	5.5	15.7	–	**20.00**	–	8.4	(Gabay et al. 1990)
22	61	232	27.5	3.9	< 1 mW	11.60	< 4 μW	**50.0**	(Marshal et al. 1994)
6	65	18.4	9.1	1.6	0.110	–	6.0	–	(Markova et al. 1978)
16	70	141	9.1	4.0	**1.20**	6.0	**8.5**	42.6	**(Markova et al. 1978)**

AIM

To study the dependence of the average laser power at the atomic Au 312.2-nm line on the active volume and gas-discharge parameters.

EXPERIMENTAL SETUP



(a) **(b)**

Fig. 1. Scheme of laser tube constructions.

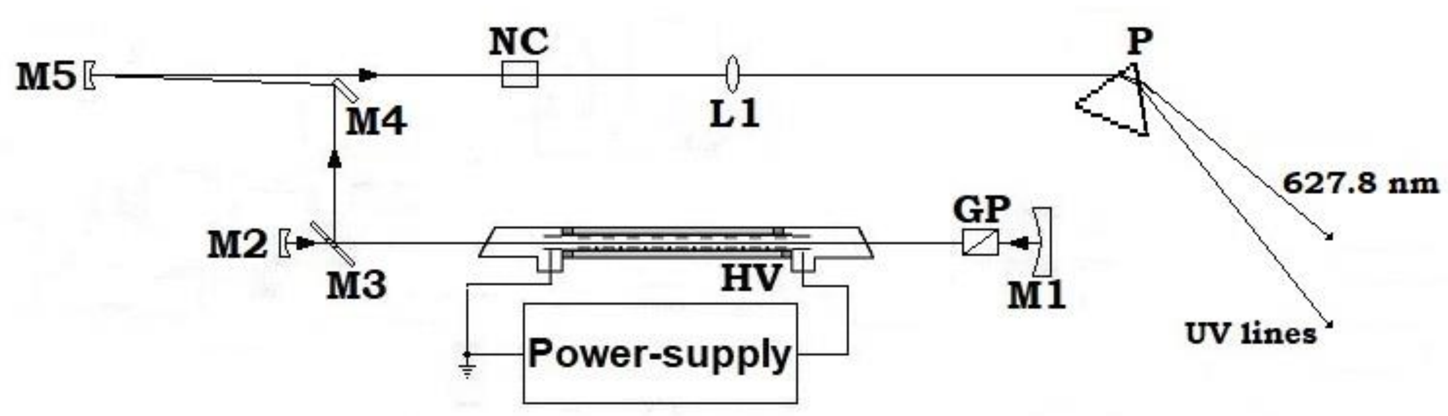


Fig. 2. Scheme of frequency conversion setup.

Table 2. Parameters of optical elements.

Optics	M1	M2	M3		M4	M5	L1
Focal length (cm)	100	5	∞	0.5-mm orifice	∞	25	15

EXPERIMENTAL RESULTS

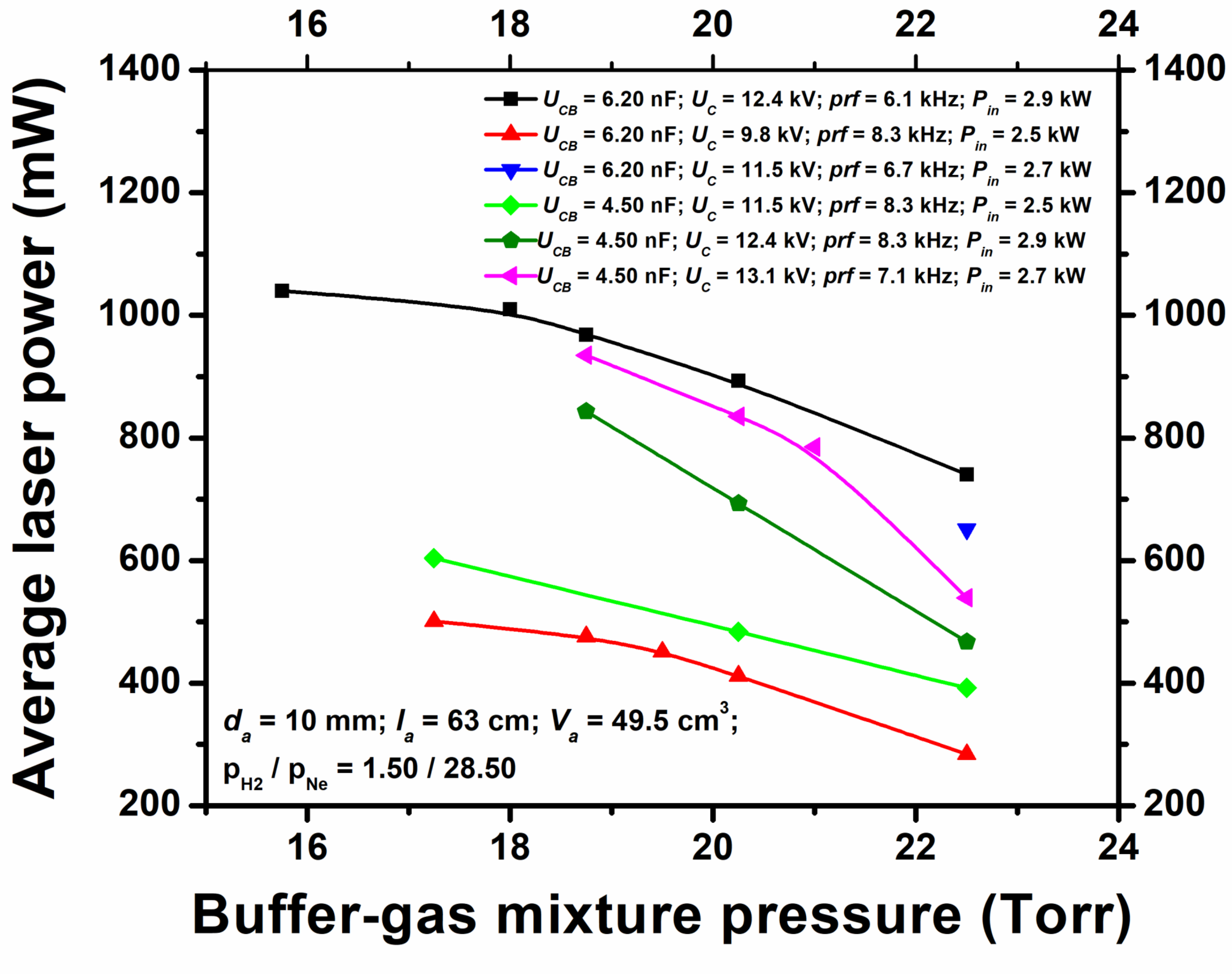


Fig. 3. Dependence of average laser power on buffer-gas mixture pressure.

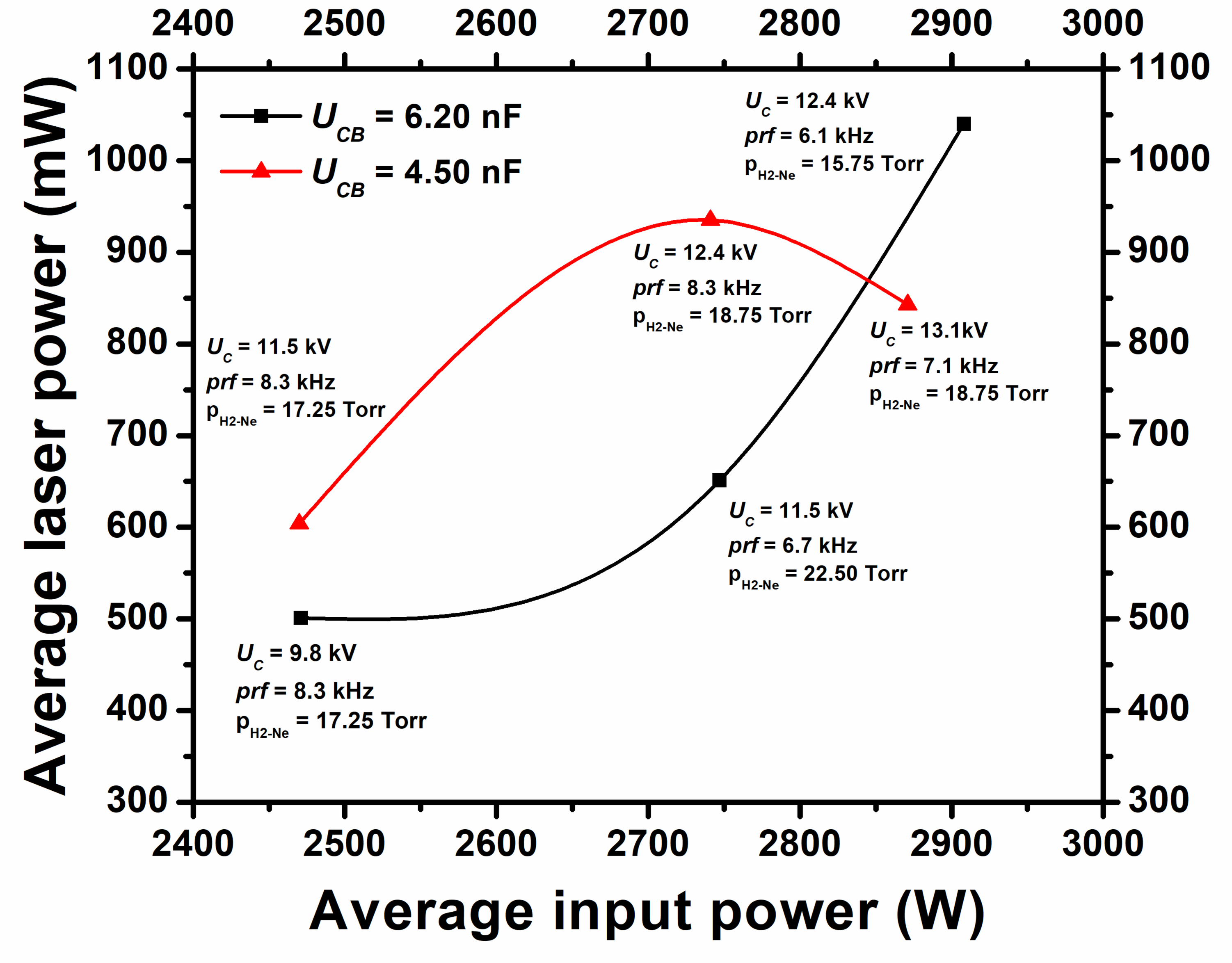


Fig. 4. Average laser power as a function of average input power.

Table 3. Features of the discharge tubes, electrical input parameters and output laser characteristics: d_a – active zone diameter; l_a – active zone length; V_a – active zone volume; C_{CB} – nominal value of capacitor bank; C_0 – nominal value of compressing circuit capacitor; C_P – nominal value of peaking capacitor; U_C – charging voltage; ***prf*** – pulse repetition frequency; P_{in} – average electrical input power; P^{UV}_{out} –average laser power at 312.2 nm; P^{Red}_{out} – average output power at 627.8 nm; $P^{UV}_{out}{}^{sp} = P_{out} / V_a$ – specific average laser power at 312.2 nm; $P^{Red}_{out}{}^{sp} = P_{out} / V_a$ – specific average output power at 627.8 nm First and second values of P^{UV}_{out} and $P^{UV}_{out}{}^{sp}$ are measured and corrected ones, respectively, taking into account losses in optical elements and air.

d_a (mm)	l_a (cm)	V_a (cm^3)	p_{H2-Ne} (mbar)	p_{H2}-p_{Ne} (mbar)	C_{CB} (nF)	C_0 (nF)	C_P (nF)	U_C (kV)	*prf* (kHz)	P_{in} (W)	P^{UV}_{out} (mW)	P^{Red}_{out} (mW)	$P^{UV}_{out}{}^{sp}$ (mW/cm^3)	$P^{Red}_{out}{}^{sp}$ (mW/cm^3)
4.5	51	8.1	20.00	0.50-19.50	3.10	0.77	0.24	13.1	7.4	1968	150	190	18.5	23.5
4.5	**51**	**8.1**	**40.00**	**1.00-39.00**	**2.33**	**0.60**	**0.24**	**13.1**	**20.0**	**3999**	**–**	**1430**	**–**	**176.5**
4	**43**	**5.4**	**25.00**	**0.00-25.00**	**4.24**	**1.00**	**0.27**	**9.8**	**10.0**	**2036**	**295**	**220**	**54.6**	**40.7**
6	53	15.0	22.00	1.10-20.90	2.80	0.70	0.24	13.1	10.0	2403	696	588	46.4	39.2
8	53	26.6	15.00	0.75-14.25	4.50	1.10	0.36	13.1	7.1	2741	901	600	33.9	22.6
10	**63**	**49.5**	**21.00**	**1.05-19.95**	**6.20**	**1.20**	**0.35**	**12.4**	**6.1**	**2908**	**1040**	**590**	**21.0**	**11.9**
15	63	111.3	18.00	0.90-17.10	8.00	1.90	0.50	13.1	6.25	4290	601	640	5.4	5.8

Acknowledgements: **This work was supported by the Project KP-06-H77/8 "Development and basic research of high-beam-quality laser system oscillating in ultraviolet spectral range" of Bulgarian National Science Fund.**

CONCLUSIONS

Active volume scaling of the gold vapor laser is carried out. Maximal average laser power obtained at the 312.2-nm line is 1.02 W. SAOPs of 176 and 54.6 mW.cm^{-3}. are achieved at the 627.8-nm and 312.2-nm lines, respectively. The obtained SAOPs are 3.5 and 6.7 times higher than the values reported so far at the 627.8-nm and 312.2-nm lines, respectively. Improving the beam-quality with an unstable cavity and polarizing the laser beam, sum frequency generation of the two atomic Au lines at 208.5 nm is obtained for the first time through a nonlinear BBO crystal. Second harmonic generation of the 627.8-nm line at the 313.9-nm line is also produced.