Metal-ion transition lasers with transverse HF excitation

E. L. Latush, V. S. Mikhalevskiĭ, M. F. Sém, G. N. Tolmachev, and V. Ya. Khasilov

Physics Research Institute
(Submitted June 12, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **24**, No. 2, 81–83 (20 July 1976)

We report attainment of cw lasing with transitions of thallium, cadmium, zinc, mercury, and selenium ions pumped by groups of fast electrons produced in a transverse HF discharge. The required metal vapor pressure was produced by self-heating.

PACS numbers: 42.60.Cz

We will report here cw lasing obtained with a number of transitions of thallium, cadmium, zinc, mercury, and selenium ions pumped by fast electrons produced in a transverse HF discharge. The required vapor pressure of the metal was produced by self-heating.

Discharge in a hollow cathode is extensively used to excite the active medium in metal-vapor lasers.[1-3] The presence of a group of fast electrons in this type of discharge makes it possible to produce in the active volume a relatively larger vapor pressure of the working medium without lowering the concentrations of the ions and of the metastable atoms of the buffer gas. This leads to effective lasing in the hollow cathode via ionic transitions populated both by charge exchange and by the Penning process. A shortcoming of such lasers is that the discharge is not uniform over the length, particularly in the cw regime, and there is a tendency for an arc to be ignited.

In the present study we have used, for the first time, a transverse HF discharge to excite the active medium of metal-vapor lasers.

It was shown in [4] that a group of fast electrons can appear under definite conditions in the near-electrode regions of an HF discharge, where large stationary electric fields are produced. In this case, in analogy with the hollow cathode, one can hope to obtain effective population of the ionic laser levels, and it was this which stimulated us to employ this type of discharge to excite the active media in metal-vapor lasers.

Element	Wavelength,nm	Buffer gas	Pump mechanism
Tl	695.0	Ne	Charge exchange
	594.9	Ne	Charge exchange
	515.2	He	Charge exchange
Cd	806.6	He	Charge exchange
	537.8	He	Charge exchange
	533.7	He	Charge exchange
	441.6	He	Penning process
	325.0	He	Penning process
Zn	589.4	He	Penning process
	492.4	He	Charge exchange
	491.1	He	Charge exchange
Hg	794.4	He	Charge exchange
	615.0	He	Charge exchange
Se	530.5	He	Charge exchange
	522.7	He	Charge exchange
	517.5	He	Charge exchange
	506.8	He	Charge exchange

The active part of the discharge tube was made of quartz with inside diameter 8 mm and length 80 cm. Nickel electrodes 1 cm wide were placed in parallel along the external surface of the tube and clamped to the latter with quartz rings. Pieces of the working medium were placed inside the tube uniformly along the active zone. The discharge was maintained by an HF generator operating at 5.28 MHz and with an approximate average output power 500 W. The necessary metal vapor pressure was produced by self-heating. The power fed to the discharge was insufficient to produce in tubes of this volume a working-medium vapor concentration sufficient for lasing by thermal heating along, and we assume that the vapors were fed to the discharge also as a result of HF heating of the metal, ion bombardment, and detachment from the walls.[5] At large pump powers, overheating of the metal took place, and this forced us to operate in a quasi-intermittent regime with a pump pulse duration 1 msec and a repetition frequency 300—1000 Hz. All the initial characteristics were subsequently recalculated with allowance for this operating regime.

We obtained cw lasing on most transitions in the ion spectra of Tl, Cd, Zn, Hg, and Se, which were observed by us both in a hollow cathode [1-3] and in a direct-current cataphoresis discharge.[6] The strongest of these transitions are gathered in the table. The optimal buffer-gas pressure was larger for transitions populated by charge exchange (15 Torr) than for transitions populated by the Penning process (6 Torr).

The gain on the cited transitions was more than 20% per meter, and the total lasing power for all lines reached 50 mW for each of the elements. The intensity of the lasing increased rapidly with increasing HF pumping and had no tendency to saturation even at the maximum power input to the discharge. We have therefore assumed that the output power of these lasers can be greatly increased by increasing the HF input, and also by increasing the tube diameter and by optimizing the pump frequency and other discharge parameters.

It is important that with this type of discharge it was easy for us to obtain cw population of the cadmium ion lines, which could not be obtained under conditions of cataphoresis lasers, and that the gain with other charge-exchange lines is larger than in the positive discharge column. It should be noted that even at relatively large lengths of the active zone it was easy to obtain a discharge that was uniform over the length. This made it possible to use the working volume with maximum effectiveness.

The simplicity of design, the homogeneity of the discharge, the absence of longitudinal ion drifts, the large set of wave lengths generated by a single tube, and the possibility of greatly improving the lasing parameters, all make the use of transverse HF pumping in gas lasers promising.

[1] M. F. Sém and V. S. Mikhalevskiĭ, Zh. Prikl. Spektrosk. **6**, 668 (1967).
[2] V. S. Aleĭnikov and V. V. Ushakov, Opt. Spektrosk. **33**, 214 (1972).
[3] I. G. Ivanov and M. F. Sém, Elektronnaya tekhnika, Ser. 4 "Élektrovakuumnye i gazorazryadnye pribory" (Electronic Engineering, Ser. 4, Vacuum and Gas-Discharge Devices), No. 2, 12 (1974).
[4] A. A. Kuzovnikov and V. P. Savinov, Radiotekh. Élektron. **18**, 816 (1973).
[5] G. M. Mishakov and A. M. Shukhtin, Opt. Spektrosk. **32**, 1006 (1972).
[6] V. F. Keĭdan, V. S. Mikhalevskiĭ, and M. F. Sém, Zh. Prikl. Spektrosk. **14**, 331 (1971).