Investigation of a transverse E-beam initiated pulsed HF chemical laser

Sha Guohe, Yin Houming, Zhou Dazheng, Yang Guansheng, Han Denglong, Shi Shuguo, Wang Xueling, Cai Peihua, Wang Zhenqi, Li Xinhua, Wang Ruqing, Zhang Cunhao

(Dalian Institute of Chemical Physics, Academia Sinica)

We designed and tested an e-beam initiated pulsed chemical laser devices, in which the H_2/F_2 chain reaction is initiated by F atoms produced by a pulsed e-beam and population inversion in the excited vibration states of HF can thus be obtained.

The e-beam is emitted from a cold cathode electron gun, which is energized by a 240 KV high voltage pulse from a four-staged Marx generator. The e-beam current density from the e-beam output window attains $17A/cm^2$, the duration (FWHM) of e-beam pulse is about 0.4 μs, the average electron energy is about 86 KeV.

Two types of laser cavities have been tested. Their dimensions are $3.7 \times 5 \times 35$ cm^3 and $5 \times 6 \times 38$ cm^3 respectively. The constituents of the laser gas mixture include H_2, F_2, SF_6, He etc. SF_6 additive has the effect of increasing the energy deposition of e-beam and thus the concentration of F atoms. Small amount of O_2 was also added to prevent the spontaneous reaction during the mixing of F_2 with H_2.

Preliminary investigations were made on the effects upon the output laser energies of various gas composition, cavity pressures, output couplings and e-beam densities etc. With a gas composition of 20% H_2, 20% F_2, 30% SF_6, 6.4% O_2 and 23.6% He, the laser output energy increased with the gas pressure, but tended to be saturated near 450 torr. At 200 torr, the specific energy was 41.3 J/l. atm, and a single pulse energy was 8.1 J. The intrinsic electrical efficiencies were between 100% to 200% varying with different operating conditions.

The laser pulse shape was monitored by a cryogenic InSb infrared detector and displayed on a Tektronix 466 memory oscilloscope. The pulse width was 1.4 μs at a cavity pressure of 200 torr, which was over three times broader than that of the initiating e-beam.

In order to prevent the F_2/H_2 spontaneous reaction, a higher O_2 concentration (about 30% of F_2 concentration) in these experiments was used. The presence of O_2 may increase the chain-breaking rate, thus diminished the H_2-F_2 reaction chain length and the chemical efficiency. Recently, a better mixing scheme has been put to test, which could get a stable mixture of H_2-F_2 with much less O_2 concentration. A significant improvement in laser efficiency is expected by this scheme.

As 6160 J/l. atm can be released for vibrational energy of HF molecules in the highly exothermic chain reaction of H_2-F_2, sizable increase in specific energy and electrical efficiency of this laser system may be expected in our future work.

电子束引发的脉冲HF化学激光器的研究

沙国河　尹厚明　周大正　杨关生　韩登龙　史书国
王学林　蔡培华　王振歧　李新华　汪汝清　张存浩

（中国科学院大连化学物理研究所）

我们设计和试验了一个电子束引发的脉冲化学激光装置。用一个脉冲电子束产生氟原子以引发氢和氟的链反应，由此获得 HF 分子的振动激发态布居反转。

电子束由一个冷阴极电子枪发射。用四级马克斯发生器产生 240 千伏的脉冲高压加在电子枪阴极上。从电子束窗口输出的电子束电流密度达到 $17A/cm^2$，电子束脉宽（FWHM）约 0.4μ sec，平均电子能量约 86 KeV。

试验了两个激光腔体，其尺寸分别为 $3.7\times5\times35cm^3$ 和 $5\times6\times38cm^3$。所用的激光工作气体有 H_2、F_2、SF_6、He 等，加入 SF_6 可增加电子束能量的沉积而增加氟原子浓度。另外还加入少量氧以阻抑氟氢混合时的自发反应。

我们对不同的气体组成、腔压、输出耦合率、电子束电流密度等对激光输出能量的影响进行了初步考察，当气体组成为 H_2 20%，F_2 20%，SF_6 30%，O_2 6.4%，He 23.6%时，激光输出能量随气压增加而增加，但到 450 托时即达饱和。在 200 托时比能量达到 41.3 焦耳/升・大气压。获得单脉冲输出 8.1 焦耳。本征电效率随工作条件不同而在 100% 至 200% 之间。

用低温 InSb 红外探测器测量了激光脉冲波形，探测器输出显示在 Tektronix 466 记忆示波器上。当腔压为 200 托时激光脉宽为 $1.4\mu s$，为引发电子束脉宽的三倍多。

在上述试验中为了防止氢氟混合时的自发反应，应用了较高的氧含量（约占氟量的30%），由于氧的存在增加了断链速度，减小了 E_2-F_2 反应链长，因而降低了化学效率。最近，试验了一种较好的混合方式，已经可以在氧含量比过去大大降低的情况下制得 H_2-F_2 稳定混合物。我们预期这将显著地提高激光器的效率。

由于 H_2—F_2 的高放能链反应可产生 6160 焦耳/升・大气压的 HF 分子的振动能，我们期望通过进一步的努力将使此激光器的比能量和电效率大大提高。