Long Pulse Duration of F_2 Laser for 157nm Lithography

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ABSTRACT

An ultra narrow line width of the F_2 laser, narrower than 0.2pm, is required for a CaF_2 only refractive optics exposure system. Also, a low peak laser power is needed for the extension of the optics lifetime. These ultra narrow line width and low peak power are achievable by long pulse duration.
We, Association of Super-Advanced Electronics Technologies (ASET), are developing an ultra line narrowed F_2 laser below 0.2pm, with 5mJ high output energy, by adopting a 2-stage F_2 laser system, which consists of an oscillator and an amplifier. The oscillator for this 2-stage system is required to have an ultra narrow line width of below 0.2pm. We have developed F_2 laser with very long laser pulse duration of over 65ns (Tis: the integral squire pulse width), in a free running operation. And, by installing a line-narrowing module (LNM) in this F_2 laser, an ultra narrow line width of below 0.2 pm (FWHM, deconvolved) has been realized. This F_2 laser was successfully used for the oscillator of 2-stage system [1].

Keywords: F_2 laser, F_2 laser lithography, Long pulse duration, Ultra narrow line width, 2-stage system

1. INTRODUCTION

In ASET F_2 laser lithography technology project, we are developing an ultra line-narrowed F_2 laser for a CaF_2 only refractive optics exposure system. The specification targets of this F_2 laser are an ultra narrow line width of below 0.2 pm and high output energy of 5mJ, etc. In order to realize these targets, we are adopting a 2-stage F_2 laser system, which consists of an oscillator and an amplifier [1]. For the 2-stage system, we have made an oscillator F_2 laser with a line-narrowing module (LNM) inside the laser cavity, whose line width is narrower than 0.2 pm.
In case of a line narrowed excimer laser with a LNM, the spectral line width becomes narrower, by elongating the pulse duration [2]. However, the long pulse duration operation with F_2 laser had been considered to be very difficult [3].
It has been confirmed that a pulsed power module with a very fast rise time of the output voltage (a high speed PPM) obtains long pulse duration, because a temporal long homogeneous discharge is realized by the high speed PPM. A line narrowed ArF excimer laser for lithography with very long pulse duration of over 50 ns (Tis) has been developed by GIGAPHOTON INC, by using their high speed PPM [2].
We have succeeded in achieving very long pulse duration of over 65 ns (Tis) from an oscillator F_2 laser for the 2-stage system, by using a high speed PPM supplied from GIGAPHOTON Inc, and by adopting a He-Ne mixed buffer gas. A

temporal long discharge is obtained by using the He-Ne mixed buffer gas; because discharge resistance of the He-Ne mixed buffer gas is lower than that of He only buffer gas.
An ultra narrow line width of below 0.2 pm (FWHM, deconvolved) with 0.2 mJ has been obtained, by installing a LNM in the oscillator F_2 laser. And by using this laser as the oscillator for 2-stage system, we have achieved below 0.2 pm with high output energy of 15 mJ [1)].

2. LONG PULSE DURATION OF F_2 LASER AND CONSIDERATION

Fig. 1 compares the laser pulse shape in free running operation of the oscillator F_2 laser with that of our old F_2 laser. In the oscillator F_2 laser, the high speed PPM from GIGAPHOTON is used whose output voltage rise time is fast, about 70 ns. The output voltage rise time of the PPM in the old F_2 laser, about 90 ns, is slower than that of the oscillator F_2 laser. For both F_2 lasers, He buffer gas was used. From Fig. 1, it is found that the laser pulse shape from the oscillator F_2 laser has 2 peaks, so that the laser pulse duration (Tis) is longer than that of the old one. It is considered that a temporal long homogeneous discharge is realized by the high speed PPM, consequently the longer laser pulse duration is realized in a F_2 laser, by using a high speed PPM. Fig. 2 shows the laser pulse duration of the oscillator F_2 laser with He only buffer gas and with various mixing ratio He-Ne buffer gases. By increasing Ne mixing ratio, the decay time of the laser pulse becomes slower, and longer pulse durations are obtained, from about 20ns to about 45ns. On the other hand, a peak power and output energy of the laser pulse becomes lower. As a lower discharge resistance is obtained by increasing Ne mixing ratio, the laser pulse duration is considered to become longer. Moreover, we consider that the high speed PPM realizes such a long pulse with the He-Ne mixed gas. Even though He-Ne mixed gas is used, long pulse duration is not obtained from our old F_2 laser whose voltage rise time is slow, as mentioned above.
Fig. 3 shows measured laser pulse shapes of the oscillator F_2 laser, by changing the reflectance of the laser cavity output coupler. By increasing the reflectance, the pulse duration becomes longer. The output energy, however, shows the maximum at the reflectance of about 40 %, in the oscillator F_2 laser.

3. LINE NARROWING AND COSIDERATION

Fig. 4 and Fig.5 are a laser pulse and a spectral shape of the oscillator F_2 laser with a LNM, respectively. The LNM consists of expansion prisms and a grating. The pulse duration of 22 ns is shorter than that in free running operation. The output energy was 0.2 mJ, which is remarkably lower than output energy of 4 mJ in free running. This short duration and low output energy are due to large optical loss of the LNM. Therefore, by reducing the LNM loss, much longer pulse duration and much narrower line width will surely be obtained.

4. CONCLUSION

We have developed a F_2 laser with very long laser pulse duration of 65 ns (Tis). It has been confirmed that long pulse duration in a F_2 laser is achieved by using a pulsed power module with a very fast rise time of the output voltage (a high speed PPM) and using a He-Ne mixed buffer gas. And, by installing a line-narrowing module (LNM) in the F_2 laser, an

ultra-narrow line width of below 0.2 pm has been obtained. Long pulse duration is considered to realize such narrow line width. As the optical loss of the LNM is very large, much narrower line width will be achieved by reducing the LNM loss, By applying this F_2 laser with the LNM for an oscillator of 2-stage system, an ultra narrow line width of below 0.2pm with a high output energy of 15 mJ has been obtained [1)].

We believe that 2-stage F_2 laser system, in which an oscillator with such long pulse duration is used, will be utilized for a CaF_2 only refractive optics exposure system.

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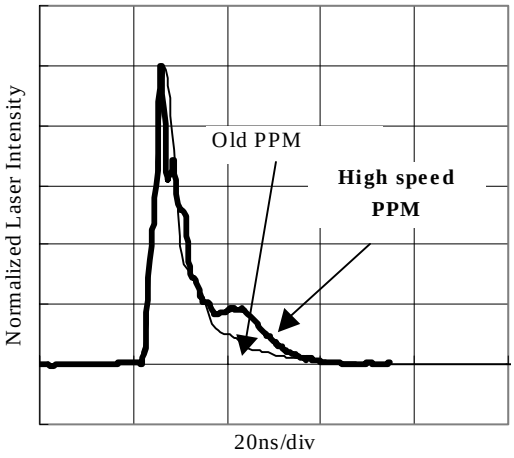

Fig.1 Laser pulse shapes with the high speed PPM and the old PPM

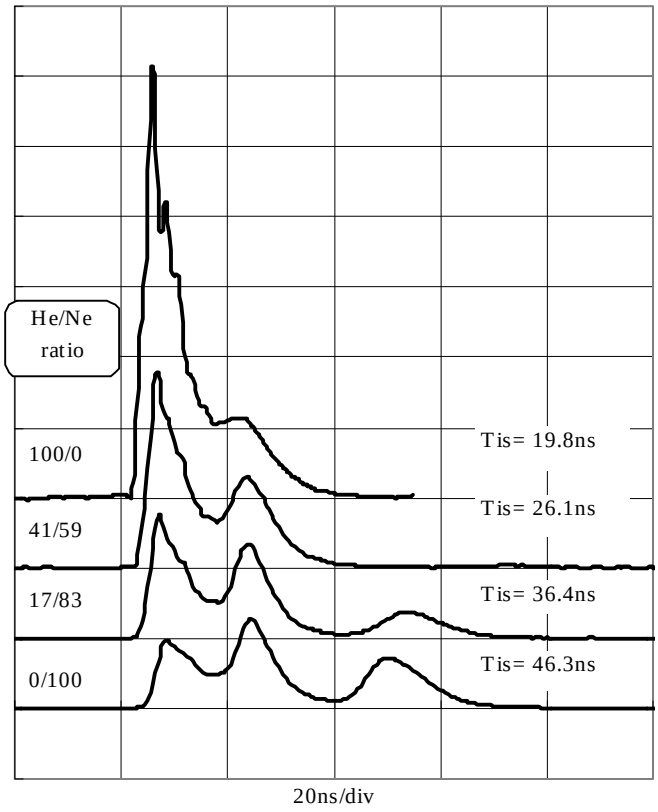

Fig. 2 Laser pulse shapes for various He-Ne mixing ratio

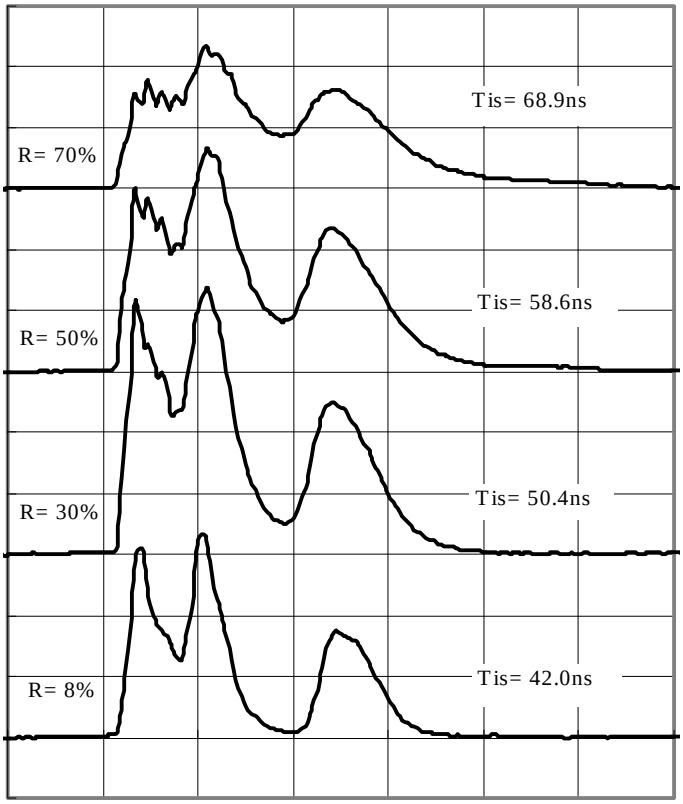

Fig. 3 Laser pulse shapes for various output couplers of laser cavity

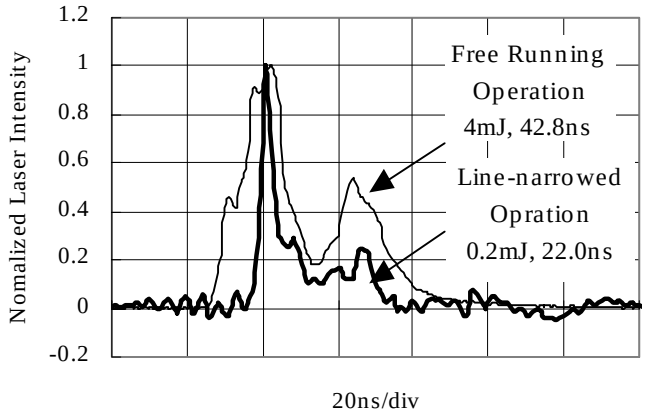

Fig. 4 Laser pulse shapes in a free running and a line narrowed operation

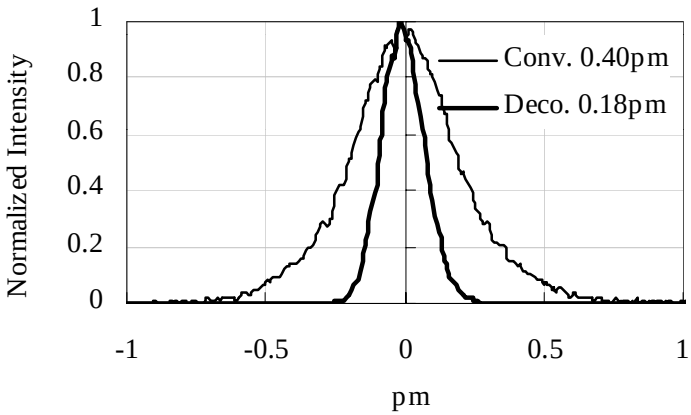

Fig. 5 Laser spectral shape in a line narrowed operation