

# Hydrogen Fluoride Chemical Laser Amplifier Performance: Experiment

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Performance data for a continuous-wave hydrogen fluoride (cw HF) chemical laser master oscillator/power amplifier showed that, regardless of the oscillator or resonator used to generate the input beam, the amplification ratio is an inverse function of the input power (intensity) and, for maximum amplification, the peak of the input intensity distribution must be matched to the peak of the zero power gain distribution in the amplifier. The match/mismatch of the oscillator/amplifier flowfields has a second-order effect on amplifier performance. The measured  $P_{out}$  vs  $P_{in}$  performance curve showed that, after a continuous increase, the difference  $P_{out} - P_{in}$  remained almost constant over a wide range of input powers. These data showed that between one-third and one-half of the device's oscillator output must be input to obtain amplifier output equal to the device's oscillator performance. When the input beam contained time-dependent oscillations, the amplitude modulation of the output beam was reduced by a factor that equaled the amplification ratio of the amplifier.

## Nomenclature

- $P_{in}$  = input power to the amplifier  
 $P_{out}$  = output power from the amplifier  
 $X_{ib}$  = distance of the optical axis of the input beam  
 downstream from the  $H_2$  injectors of the amplifier  
 $\Delta$  =  $P_{out} - P_{in}$

## I. Introduction

A REVIEW of the open literature on master oscillator/power amplifier configurations showed that there are very few data. The most extensive work was that done by UTRC.<sup>1</sup> However, due to the spectral mismatch between the oscillator and the amplifier, only  $P_1(4)$  single-line amplification data for one location of the optical axis of the input beam were obtained. The experiments by Hoffman et al.<sup>2</sup> and Patterson et al.<sup>3</sup> were with pulsed HF and KrF systems, respectively. The recent cw HF amplifier work by Bernard et al.<sup>4</sup> used an optical trombone to constructively combine two amplified beams. The constructive beam combination was verified with a Michelson interferometer. The present experiments provide the first extensive data on cw HF amplifier performance as a function of input power, location of the optical axis of the input beam, flowfield match/mismatch between the oscillator and amplifier, flow rates in the amplifier, oscillator resonator type (stable or unstable), and the time-dependent oscillations of the input beam.

A Helios CL I laser (15 cm gain length) or a Helios CL II laser (30 cm gain length) was used as the oscillator while another Helios CL II laser was used as the amplifier. The CL IIs are identical, two-channel, arc-driven, subsonic, cw HF chemical lasers. The flow channel of the CL I laser is identical to one of the flow channels of the CL II lasers. This permits the flowfields of the oscillator and amplifier to be identical when the CL I laser is run at one-half the flow rates of the CL II laser. Section II presents the experimental zero power gain data for the amplifier. Section III contains experimental amplifier performance data. The effects of the resonator and

time-dependent oscillations on amplifier performance are presented in Sec. IV. Section V contains concluding remarks.

## II. Zero Power Gain Measurements

Zero power gain (ZPG) is the gain measured when the intensity of the probe beam is low enough that the probe beam does not perturb the media. This gain is often referred to as the small signal gain. Preliminary amplifier measurements<sup>5</sup> showed that the amplifier gain is inversely proportional to input power (intensity). An increase in input power results in an increase in input intensity, which in turn stimulates more radiation and begins to saturate the gain. As the input power decreases, the gain in the amplifier increases until at some point ( $P_{in}$  ZPG), it becomes equal to the zero power gain. Further decrease of the input power does not have any effect on the gain measured. This is the criterion for determining when the zero power gain region has been reached. A power less than or equal to  $P_{in}$  ZPG was used to measure zero power gain.

The CL I (operated single line for the zero power gain experiments and multiline for the amplifier experiments) was used as the oscillator. At the pressure and temperature of the flow in the gain zone of the CL I, the HF line width is about 400 MHz. With a mirror spacing of 1 m, there were only one or two longitudinal modes lasing. The CL II flow channel is 3.0 mm high and 355.6 mm wide with a clear aperture 3.0 mm high  $\times$  40.0 mm wide. A schematic of the experimental layout is shown in Fig. 1. The input beam from the CL I was reduced in size by a two-lens telescope (first lens 250 mm focal length  $CaF_2$  plano-convex, second lens -50 mm focal length  $CaF_2$  plano-concave) to eliminate clipping of the input beam by the amplifier flow channel. The optical axis of the input beam was centered on the location of the  $H_2$  injectors and passed through the CL II parallel to the  $H_2$  injectors ( $X_{ib} = 0$ ). This locates the optical axis of the beam within the CL II amplifier gain medium so that the beam geometry in the amplifier gain medium is similar to the beam geometry in the oscillator gain medium. By moving the translation stage on which the injection optics (the #2 turning mirror and the telescope) were located, the axis of the input beam was moved downstream of the  $H_2$  injectors to measure amplification as a function of the location of the axis of the input beam,  $X_{ib}$ .

The input power required to measure the zero power gain of each line was obtained by measuring the amplification ratio ( $AR = P_{out}/P_{in}$ ) as a function of the input power at the point in the amplifier flowfield corresponding to maximum ampli-

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