

Hydrogen Fluoride Chemical Laser Multiple-Pass Amplifier Performance

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The performance of a continuous wave hydrogen fluoride chemical laser master oscillator with power amplifier was measured as a function of input power, the number of passes through the gain medium, and location of the optical axis of the input beam. The amplification ratio is an inverse function of the input power (intensity) and, for maximum amplification, the peak of the intensity distribution must be matched to that of the zero power gain distribution in the amplifier. A substantial performance advantage was measured with two-pass amplification when the two passes overlapped at least 60% and filled less than 84% of the zero power gain zone of the amplifier. The measured two-pass P_{out} vs P_{in} performance curve was significantly above the single-pass data and showed that only one-sixth of a device's oscillator output must be input to obtain two-pass amplifier output equal to the device's oscillator performance. An amplifier performance model that predicts a device's amplifier performance given the device's oscillator performance as a function of reflectivity was extended to predict multiple-pass amplifier performance. The two-pass model predictions were in good agreement with the measured two-pass amplifier performance data. The predicted amplifier performance as a function of gain length was found to be independent of device and showed that, with a 1-m gain length, one oscillator may be able to drive as many as 12 two-pass amplifiers.

Nomenclature

AR	= amplification ratio, P_{out}/P_{in}
L_e	= thickness of the mixed flow (= L_g when fully mixed)
L_g	= geometric gain length
P_{in}	= input power to the amplifier
P_{outAMP}	= P_{out} = output power from the amplifier
P_{outOSC}	= output power from the oscillator
R_{eff}	= effective reflectivity of the oscillator's resonator, = reflectivity of the outcoupler mirror times that of the feedback mirror
X_{ib}	= distance between the optical axis of the input beam and the H_2 injectors of the amplifier
Δ	= $P_{out} - P_{in}$
ζ_{in}	= nondimensional input power, = $\frac{\text{input power to the amplifier}}{\text{output power from the oscillator at } R_{eff} = 20\%}$
ζ_{out}	= nondimensional output power, = $\frac{\text{output power from the amplifier}}{\text{output power from the oscillator at } R_{eff} = 20\%}$

I. Introduction

THE calculations presented in Refs. 1 and 2 showed how a device's single-pass amplifier performance, P_{out} vs P_{in} and AR vs P_{in} , increased as the device's gain length was scaled from 0.3 to 4 m. The results of these calculations showed that, independent of device, a 4-m laser may be able to drive as many as eight amplifiers if the amplifiers are to produce as much power as could be obtained by running them as oscillators. All of these results are based on single-pass amplification of the input beam. To determine the effect of multiple-pass amplification of the input beam on amplifier performance, the amplifier performance model presented in Refs. 1 and 2 was extended to predict multiple-pass amplifier performance. In particular, the amplifier performance of the University of Illinois at Urbana-Champaign (UIUC), Helios, and CL

XI lasers was calculated for two-, three-, and four-pass amplification of the input beam through the amplifier.

The multiple-pass amplifier performance calculations showed that amplifier performance increased with multiple-pass amplification of the input beam through the amplifier's gain medium. In particular, it was found that the P_{in} required to achieve amplifier P_{out} equal to the device's oscillator P_{outOSC} decreased with multiple-pass amplification. This result indicated that an oscillator can drive more amplifiers with multiple-pass amplification. To determine if this performance increase is realized experimentally, the amplifier performance of the UIUC CL II (a two-channel, arc-driven, subsonic, continuous-wave hydrogen fluoride chemical laser with a 30-cm gain length) was measured for two and three passes through the gain medium.

The analytical model to predict multiple-pass amplifier performance is introduced in Sec. II. Section III contains several multiple-pass amplifier performance calculations. The experimental multiple-pass amplifier performance data for three different alignment configurations are presented in Sec. IV. Several concluding remarks are given in Sec. V.

II. Multiple-Pass Amplifier Model

The amplifier model^{1,2} is based on the observation that the average gain in the amplifier will be the same as the saturated gain in the oscillator when the circulating radiative flux in the oscillator is the same as the average radiative flux in the amplifier. For a multiple-pass amplifier, the P_{out} for pass $N - 1$ is the P_{in} for pass N . With the assumption that the optical paths of all the passes coincide, an approximation of the average radiative flux in the amplifier after N passes is given by

$$P_{avAMP} = \frac{1}{2} (P_{in} + P_{outN}) + \sum_{i=1}^{N-1} P_{out_i} \quad (1)$$

where P_{in} is the initial P_{in} for pass one. Since the saturated gain in an oscillator is the same as the average gain in the amplifier when the circulating radiative flux in the oscillator is the same as the average radiative flux in the amplifier,

$$\alpha_{AMP} = \alpha_{SAT} = \frac{1}{2L_e} \ell_n(R_{eff}) \quad (2)$$

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