Mathematical Model for Investigating the Performance Characteristics of Distributed Feedback Dye Lasers

Matthew Vaughn[1], Ross Dickinson[2], and Laszlo Ujj[2]

[1]Department of Mathematics and Statistics, University of West Florida, Pensacola, Fl 32514
[2]Department of Physics, University of West Florida, Pensacola, Fl 32514

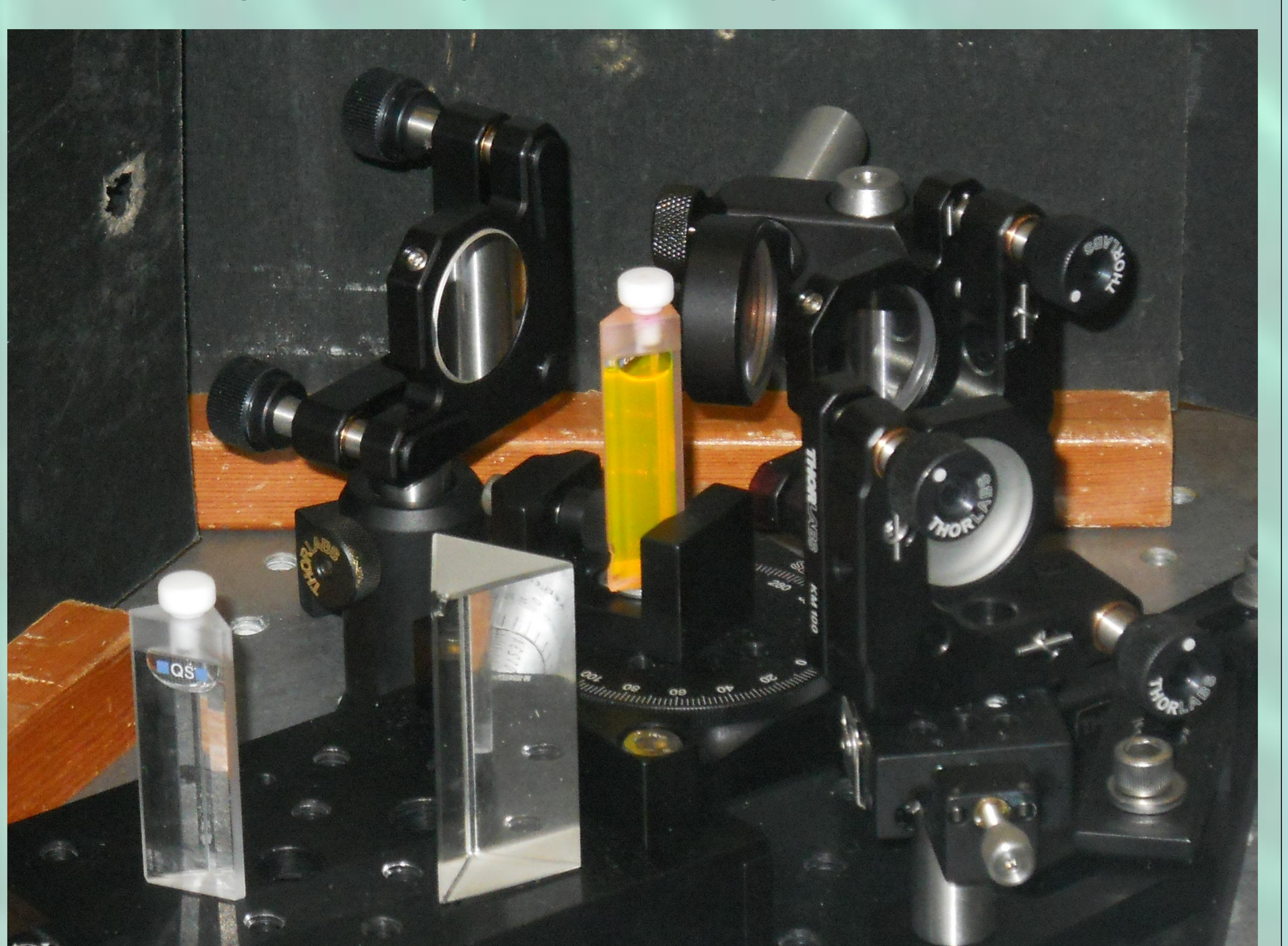
Abstract

A mathematical model is applied, in Maplesoft Maple 13, for a tunable Distributed Feedback Dye Laser (DFDL)[1] [3][4], capable of generating picosecond pluses in the microjoule energy range. The model based upon rate equations, describing the molecular and photon population dynamics involved in the operation of the laser. The model describes, from past work [3], a laser functioning by interfering laser beams creating Bragg scattering, to produce spatial modulation in the index of refraction and optical gain in the active medium. The laser can generate short optical pulses, three orders of magnitude shorter than the pump pulse. The applied model can be extended to design a new type of DFB laser, producing broadband radiation on the picosecond time scale. Numerical calculations [2] are used to evaluate physical parameters prerequisite to the design such a broadband laser. A prototype DFDL built in the Spectroscopy and Laser Laboratory of SSE, UWF.

[1] W. T. Silfvast, Laser Fundamentals. Cambridge: University of Cambridge (2003).
[2] F. Wright, Computing with Maple. New York: Chapman & Hall/CRC (2002).
[3] Z. Bor, " Tunable Picosecond Pulse Generation by an N_2 Laser Pumped Self Q-Switched Distributed Feedback Dye Laser", IEEE Journal of Quantum Electronics, Vol. QE-16, No. 5 (1980).
[4] J. Hebling, "20 ps Pulse Generation by an Excimer Laser Pumped Double Self-Q-Switched Distributed Feedback Dye Laser", Applied Physics B, 47, 267-272 (1988).

Setup

Project of Refractive index modulated DFB laser, Department of Physics, SSE, University of West Florida



Rate Equation Model of DFDL

$$\frac{dN(t)}{dt} = I_p(t)\sigma_p\left(N_{GRo} - N(t)\right) - \frac{\sigma_e c}{\eta_l} N(t)Q(t) - \frac{N(t)}{\tau_f}$$

$$\frac{dQ(t)}{dt} = \frac{\sigma_e c}{\eta_l} N(t)Q(t) - \frac{Q(t)}{\tau_c} + \frac{\Omega N(t)}{\tau_f}$$

$$\tau_c(t) = \frac{\eta_l L^3}{8\pi^2 c}\left[\left[\left(\frac{\partial \eta}{\partial T}\right)_p \Delta T(t)\right]^2 + \left[N(t)\sigma_e Vis\right]^2\right]$$

Output Power: $$P_d = \frac{hcQ(t)}{2\lambda\tau_c(t)} Lab$$

Population density of the upper laser level: N(t)

Density of laser photons: Q(t)

Cavity lifetime: $\tau_c(t)$

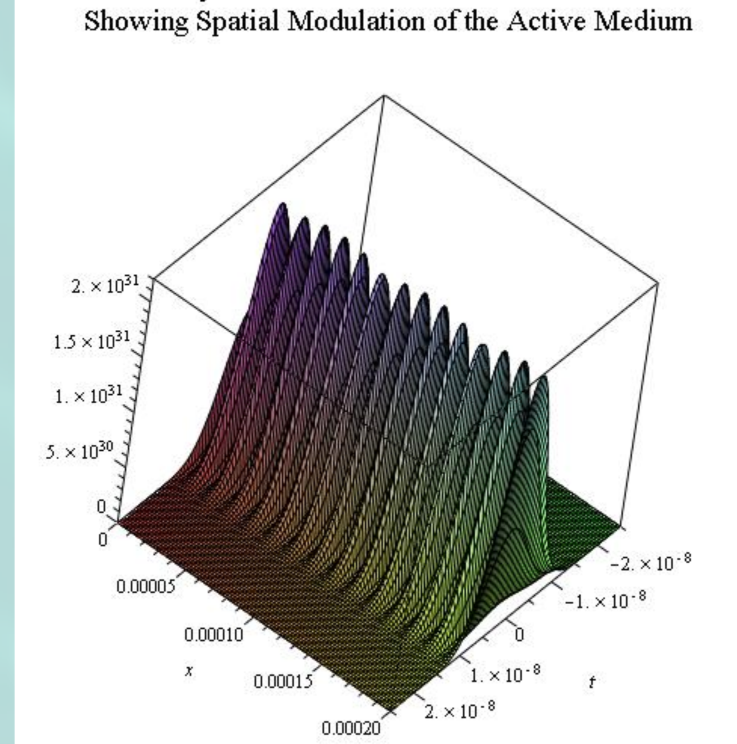
See reference [3] and [4] for the definition of other physical quantities.

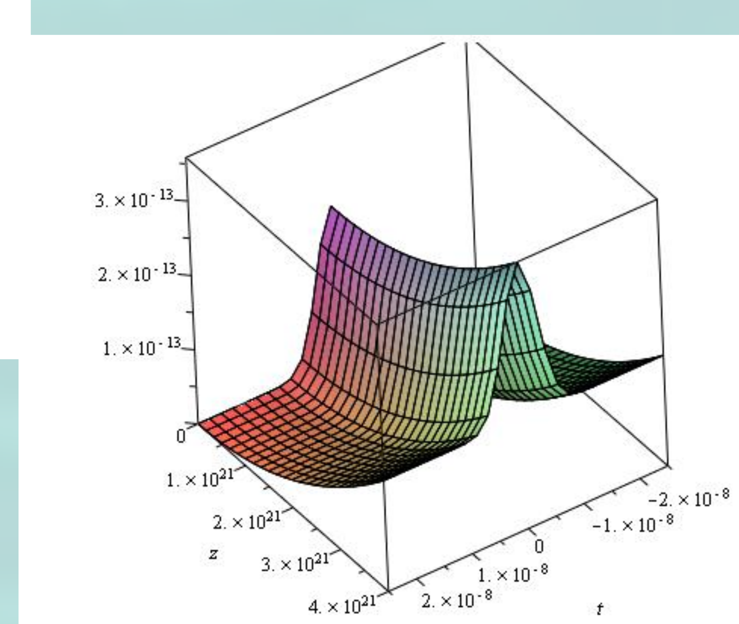
Results

ODE Solver Part of the MAPLE Code

```
c1 := evalf(Pr*(1+Visibility*cos(2*Pi*L/Lambdap)));
c2 := sigma[e]*c/IOR;
c3 := 1/FluorDT;
ivp := [(D(M))(t) = c1*(NG-M(t))*g(t)/NG-c2*M(t)*Q(t)-c3*M(t),
(D(Q))(t) = c2*M(t)*Q(t)-Q(t)/tauc(t,M(t), M(-2*HWHM) = 100, Q(-2*HWHM) = 1000];
FirstRun := rhs(dsolve(ivp,[M(t),Q(t)], numeric, maxfun = 10^6, output = listprocedure)[2]);
```

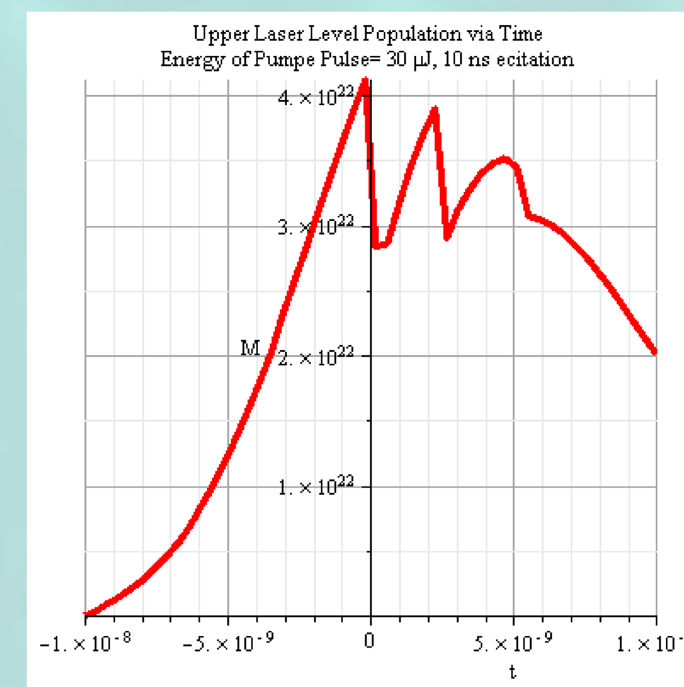
Intensity Distribution of the Inerference Pattern Showing Spatial Modulation of the Active Medium





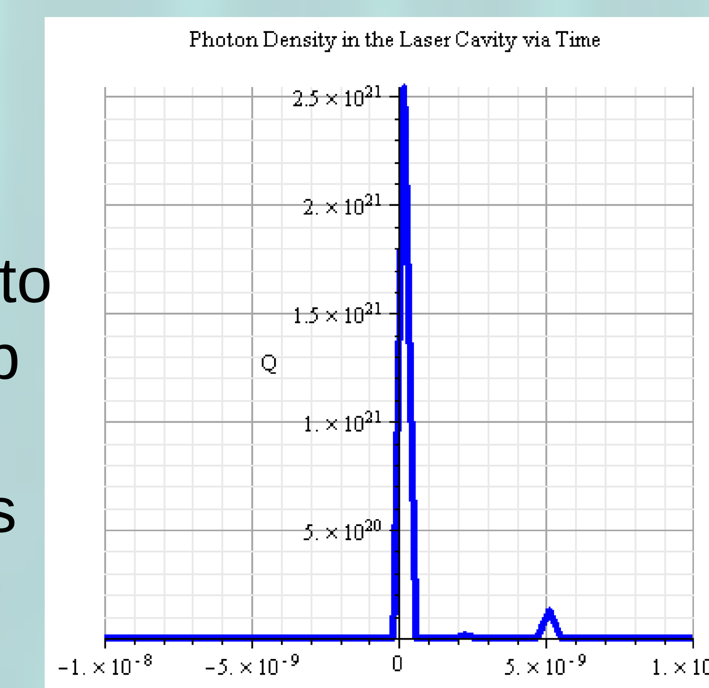
Temporal and Population Dependences of the Effective Cavity Lifetime

Short optical pulses are generated at the center of the sudden decrease of the population density of the upper laser level.



The laser is very sensitive to variation of pump -power and interference fringe pattern. Single or multiple pulses can be generated by adjusting these variables.

It is possible to generate 1000 times shorter pulses compare to the temporal width of the pump pulse. Applying 10 ns pump pulse, the output can be 10 ps or shorter.



Future Project

Construction of Nd:YAG Laser Pumped DFB-polymer-dye laser

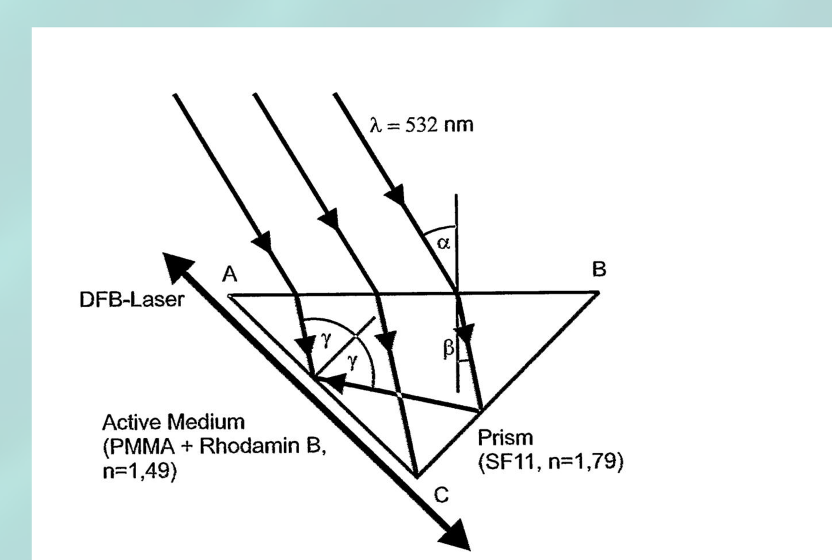


Fig. 3. Setup of the prism-DFB-polymer-dye laser

T. Voss, D. Scheel, W. Schade, Applied. Phys. B 73,105-109 (2001)