Mathematical model of an optically pumped molecular laser

Dr L R Botha, Dr C Bollig, D Esser, C Jacobs, D Preussler

SAIP 2009

Durban

CSIR
our future through science

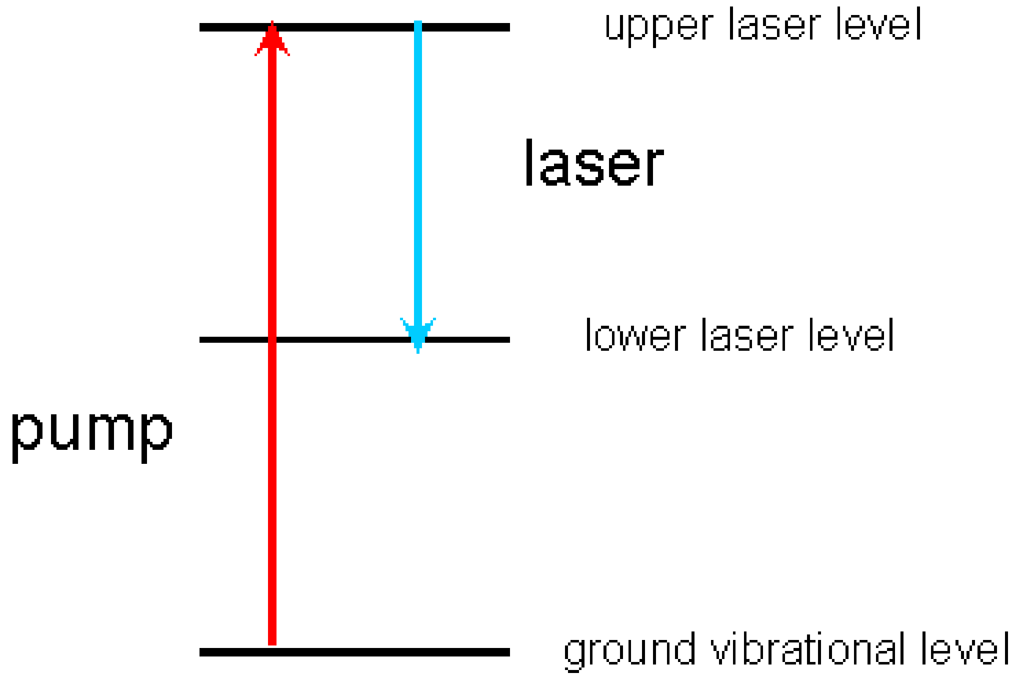
Structure of talk

- Introduction
- Overview of HBr laser
- Numerical Model
- Comparison of experimental and model results
- Conclusion

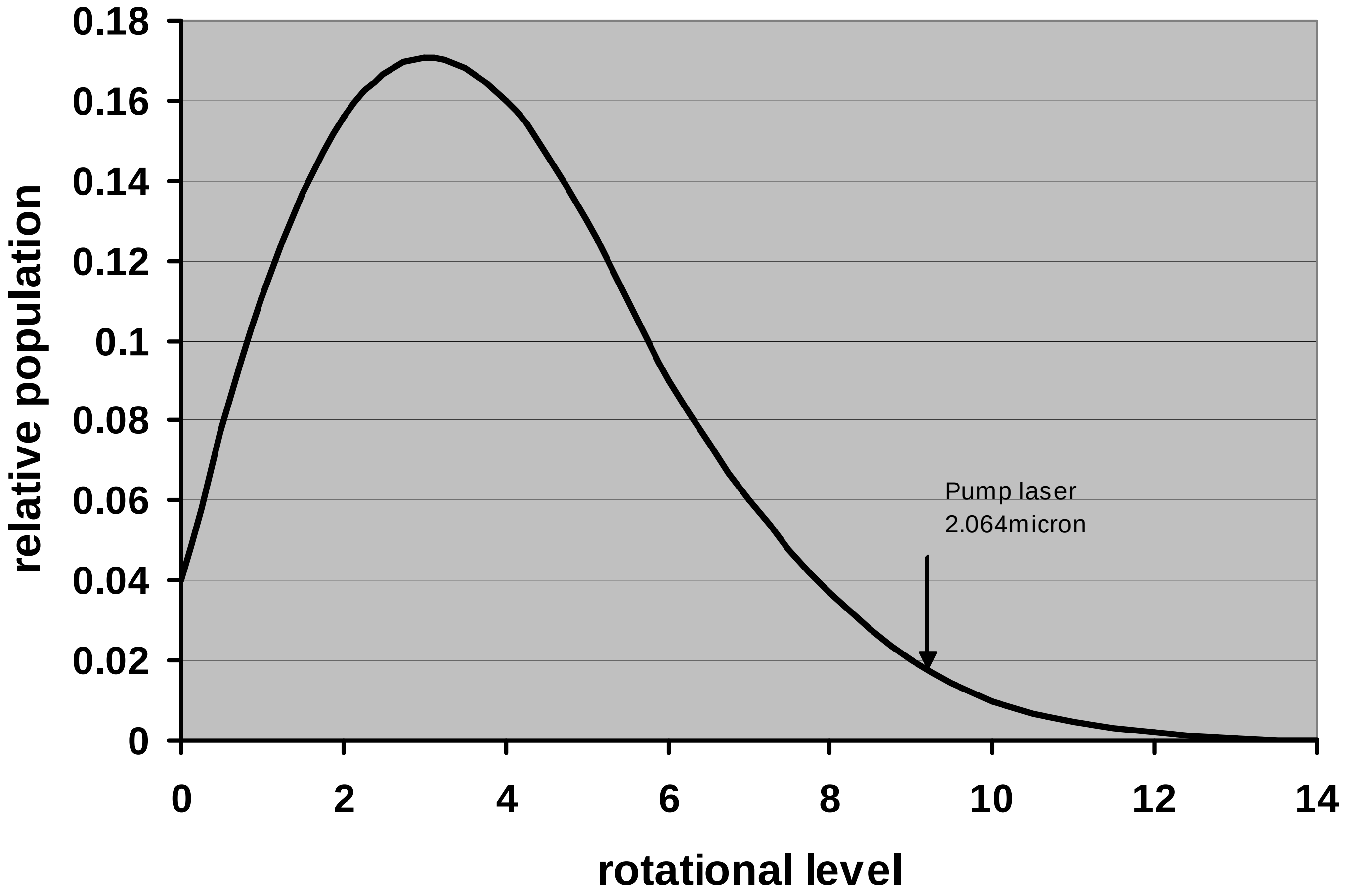
Introduction

- Mid-IR sources emitting in the 4 micron region have various applications
    - Atmospheric transmission window
    - Various molecules have absorption features in the wavelength region
    - Can be used for remote gas detection and free space communication
- Various sources do exists
    - Chemical lasers such as HF/DF
        - High energy and power possible
        - But: Complex, hazardous chemicals and bulky
    - SS pumped OPO systems
        - Compact
        - But: Difficult to scale to high energy
- Optically pumped HBr
    - Combine efficiency and compact nature of SS laser with scalability of a gas laser
- Tm pumped Ho a good candidate for producing high energy 2 micron pulses, but wavelength is a problem

HBr energy levels



Pump laser implications



Rate equation for ro-vibrational levels

- Upper ro-vibrational level

$$\frac{dn(2,j)}{dt} = \left(g_p(1,j+1)I_p(j+1) + g_R(1,j-1)I_R(j-1)\right) + \delta(\upsilon-2,j-1-j_{pump})\sigma_{Pump}I_{pump}n(0,j-1)\Big)/(hf)$$
$$-(n(2,j)-fr(2,j)V2)/\tau_R + R_{vv}^2$$

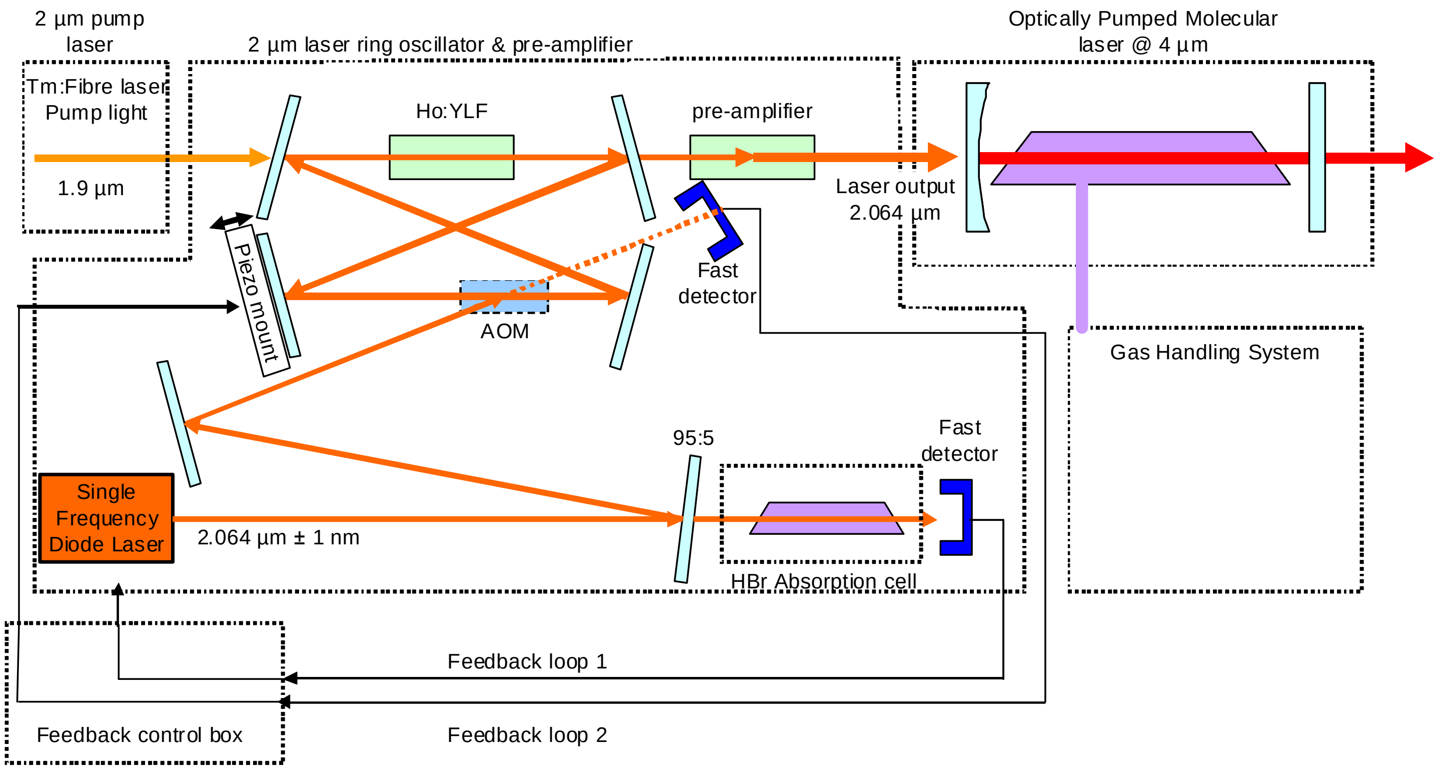
- Lower ro-vibrational level

$$\frac{dn(1,j)}{dt} = \left(-g_p(1,j+1)I_p(j+1) - g_R(1,j-1)I_R(j-1)\right)/(hf) - (n(1,j)-fr(1,j)V1)/\tau_R + R_{vv}^1$$

- Laser intensity P-transitions

$$\frac{dI_p(\upsilon,j)}{dt} = cg_p(\upsilon,j)\frac{l}{L}I_p(\upsilon,j) - \frac{I_p(\upsilon,j)}{\tau}$$

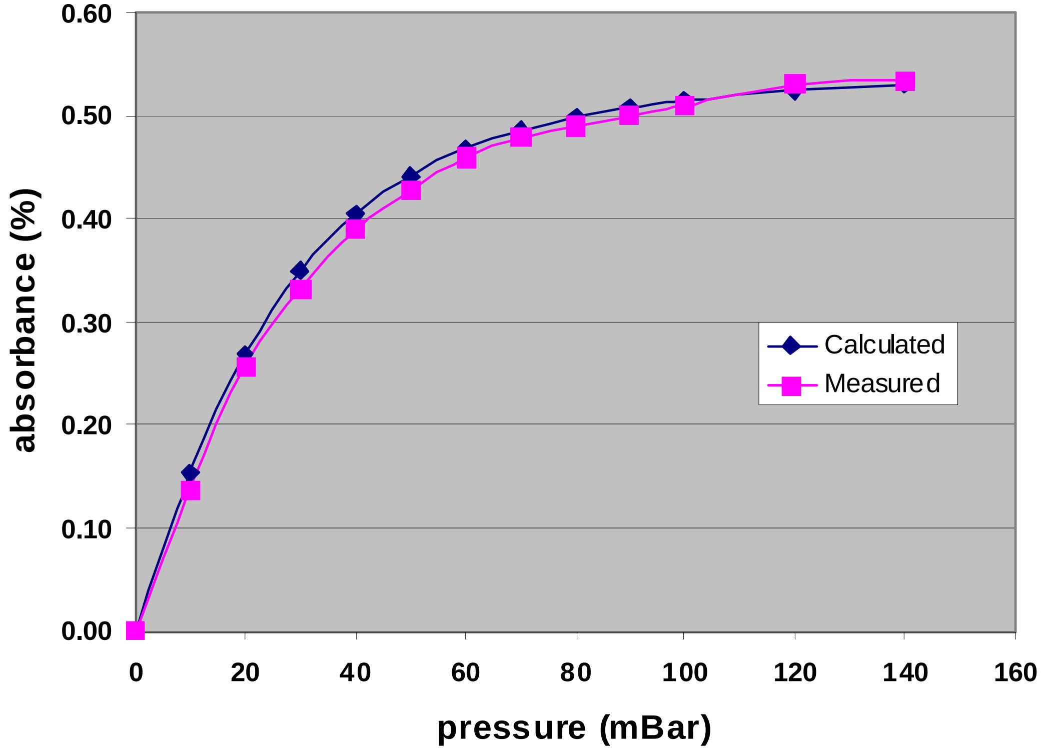
Experimental set-up



www.csir.co.za

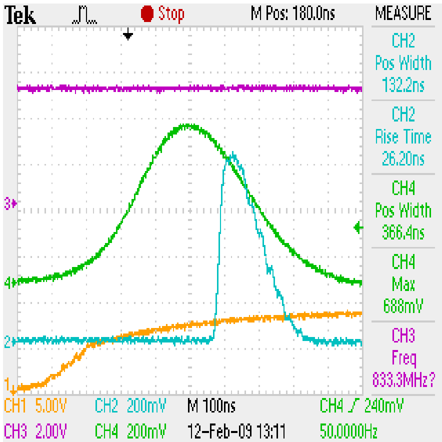
our future through science

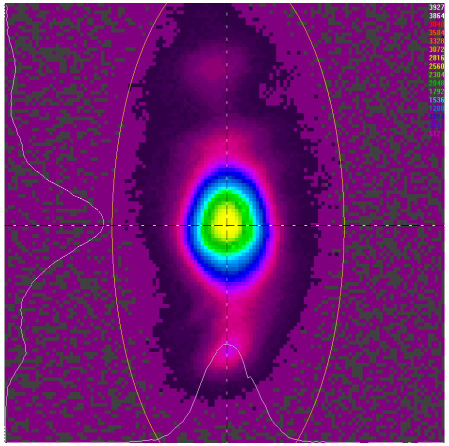
Results: Absorption as function of pressure

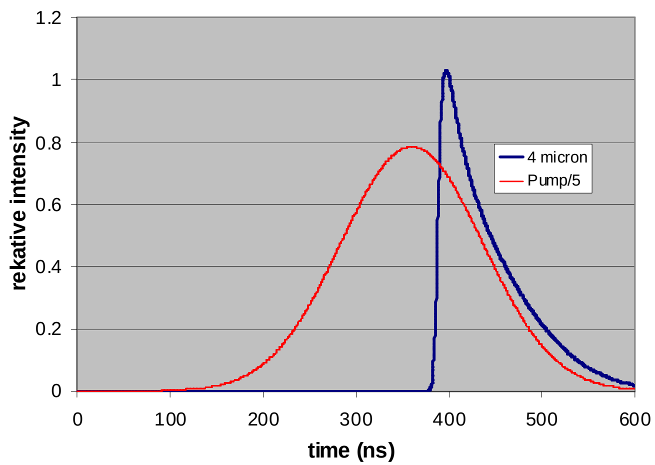


our future through science

Results: Time and spatial profile of pulse







www.csir.co.za

our future through science

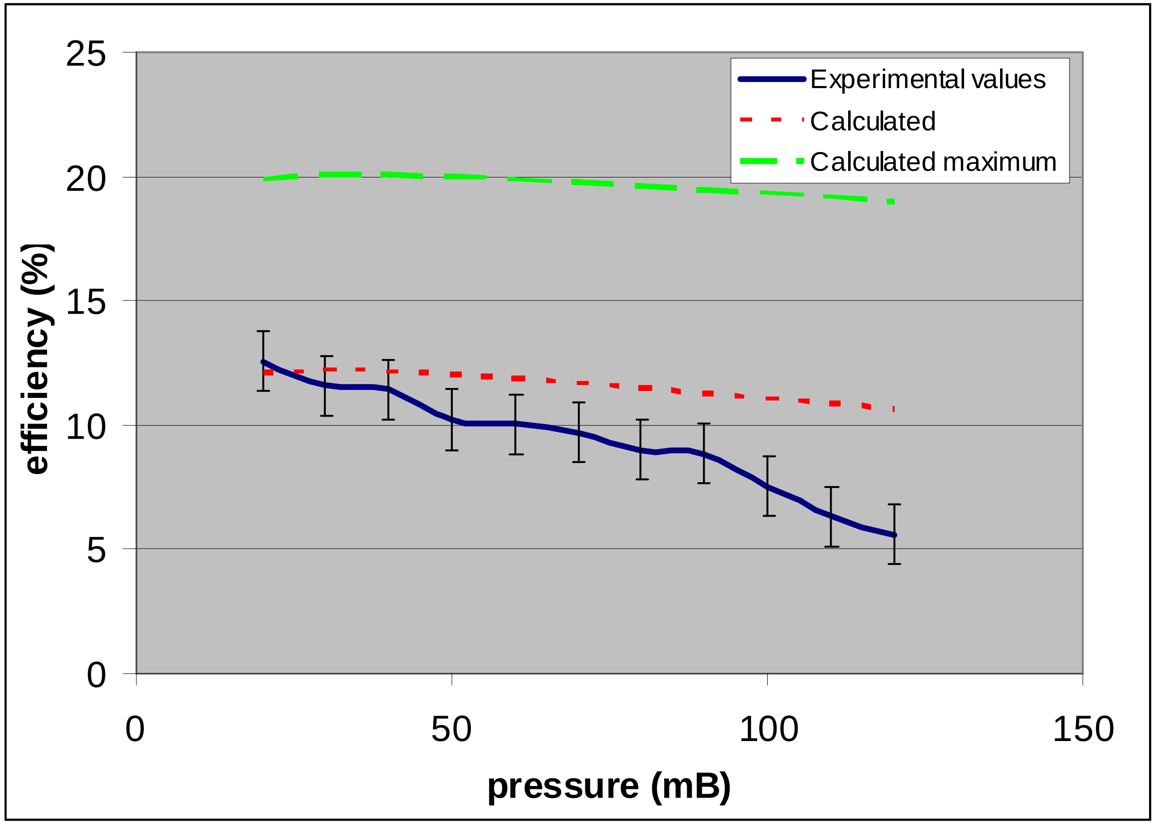
Efficiency of system:

- Theoretical maximum if no thermalization and no cascade lasing:

$$\frac{E_{laser}}{E_{pump}} = \frac{1}{\left(1+\frac{g_2}{g_1}\right)}\frac{\lambda_{pump}}{\lambda_{laser}}$$

- For our case maximum of approximately 26% if all lasing in single level
- Approximately 24% if fully thermalized, 14% if only a few of the strongest lines lase
- In practice would expect between 14% and 24%
- If system can be driven into cascade lasing much higher efficiencies possible

Measured and model calculated values



Conclusion

- A mathematical model was developed that accurately predicts the performance of an optically pumped HBr laser
- Relatively high conversion efficiency was achieved
- Tm pumped Ho:YLF is a viable source for pumping HBr laser.
- HBr can be scaled to produce high energy 4 micron pulses

Thank you

our future through science