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INERTIAL FUSION ENERGY WITH PULSED POWER*

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Demonstration of a single-shot, high-yield, fusion target is a goal of the z-pinch ICF program at SNL. The Z machine at SNL is the most powerful multi-module synchronized pulsed-power accelerator in the world. Rapid development of z-pinch targets on Z has led to outstanding progress in the last few years, resulting in radiative powers of up to 280 TW in 4 ns and a total radiated x-ray energy of 1.8 MJ. For Inertial Fusion Energy (IFE), a rep-rated fusion capability is needed. Recent developments have led to a viable conceptual approach for a rep-rated z-pinch power plant for IFE.

The rep-rated z-pinch concept exploits the advantages of going to high yield (- few GJ) at low rep-rate (- 0.1 Hz), and using a Recyclable Transmission Line (RTL) to provide the necessary standoff between the fusion target and the power plant chamber. The RTL could be cast out of a conventional power plant coolant material (such as Li or Flibe) that can be used to absorb the heat from the fusion reaction, and also to breed tritium. Vacuum is nominally required only in the RTL, which can be pumped down before loading. The chamber itself would be filled with liquid Li or solid Li with voids, chosen to mitigate the effects of the shock to the first wall. The thickness of the Li fill would typically be greater than about 1 meter, which is sufficient to absorb the bulk of the neutron energy, provide a tritium breeding ratio above unity, and thoroughly protect the first wall from neutron damage. The radius of the chamber would typically be in the range of 3 or more meters. Initial cost estimates for casting the RTL are $0.70 per shot, which is acceptable for a high-yield, low rep-rate IFE z-pinch power plant .

Current results and plans for initial work on this concept are reported for four areas: (1) experiments on Z or Saturn to test portions of transmission lines made out of suitable materials for the RTL concept; (2) calculations and possible scaled experiments to model and study shock mitigation by using a solid or liquid Li tailored density profile; (3) concept optimization studies with a systems approach to optimize RTL materials, minimize RTL cost, select first wall materials, etc.; and (4) experiments on Z or Saturn to study radiation effects on materials at power plant level fluences.

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Comparison of experimental and theoretical gain-current relations in GaInP quantum well lasers

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Abstract: We demonstrate excellent agreement between the results of a microscopic laser theory and experimental data. Theoretical results are then compared with an experimental gain versus current characteristic to reveal significant quantum well non-radiative recombination.

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AlGaInP quantum well (QW) lasers (620 -690nm) that satisfy the performance required for applications such as digital versatile disk and photo-dynamic therapy are still difficult to design. To progress we need a good description of the gain and to understand which recombination mechanisms are significant.

We performed experiments at 300K on 670nm lasers, conditions where thermally activated leakage current [1,2] is small. The structure consists of a 6.8nm wide, compressively strained, $Ga_{0.41}In_{0.59}P$ QW in an $(Al_{0.5}Ga_{0.5})_{0.51}In_{0.49}P$ wave-guide core and clad with $(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$.

We determined gain spectra and quasi-Fermi level separation from experimental transverse electric (TE) spontaneous emission spectra [3]. The measurements were converted into real units by experimentally determining the threshold loss.

To remove degrees of freedom from the calculation that allow the *fitting* of experimental data we solved the semiconductor Bloch equations, with collision effects treated at the level of quantum kinetic equations [4]. This eliminates the dephasing rate as a free parameter. It also includes contributions from non-diagonal Coulomb correlations, important in describing the shape and carrier density dependence of experimental gain spectra [5].

To ensure the correct bulk material parameters have been used we matched the results of the low carrier density ($9\times10^{22}m^{-3}$) calculation with the measured energy (1 .855eV) of the excitonic absorption peak. This allows us to compare theory and experiment at the same quasi-Fermi level separation and hence to determine the inhomogenous broadening in our lasers (l 0meV).

The calculated spectra in Fig. 1 (inhomogeneous broadening = 10meV) are in good agreement with the experimental data over a large range of injection.

We can calculate either the TE part or the total current (both polarisations). Good agreement (Fig. 2) between the experimental and theoretical TE spontaneous current leads us to believe that the calculated total spontaneous current is also a good representation of that in the real device.

Having validated the calculation we plot (line of Fig. 3) the peak gain versus total spontaneous current density. The symbols are experimental results (gain from Fig. 1 and the actual device drive current density). Additional non-radiative processes cause the difference between the two curves (dotted line of Fig. 3 corresponds to an efficiency in the well of ≈55%).

Up to now it has not been possible to determine the quantity of non-radiative recombination from a comparison of theoretical and experimental gain current relations because of the large amount of uncertainty in the calculated data. We have used an advanced microscopic semiconductor laser theory and have carefully validated the calculated output using experimental data. This allows us to determine the presence of a large quantity of non-radiative recombination in our devices. The experiments were carried out under conditions where thermally activated leakage to the cladding layers is small and so we conclude that further work is required to improve the quality of the quantum well and surrounding material.

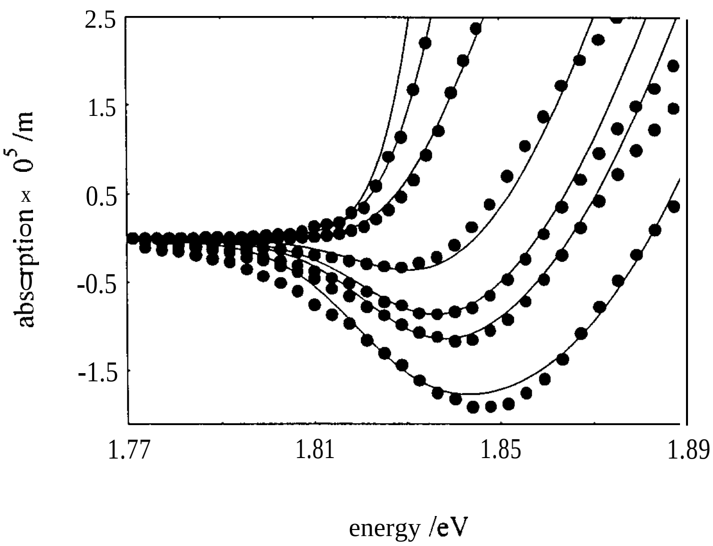
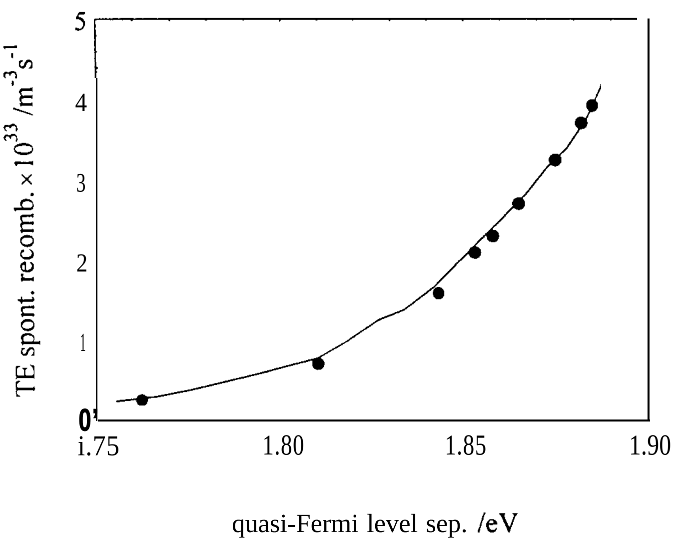


Fig. 1. Room temperature gain/absorption spectra (symbols) measured at current densities between 40 and 960 A/cm^2. The calculated spectra (lines) are for carrier densities between 6x 10^{15} m^{-2} and 3.6x 10^{16} m^{-2}



Fig, 2. Theoretical (line) and experimental (solid points) integrated TE polarised spontaneous emission spectra. The experimental data has been scaled by the same factor as the gain spectra.

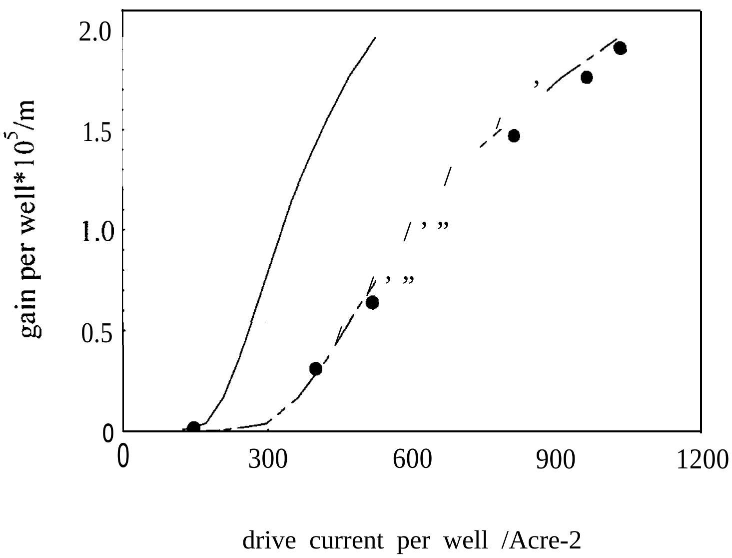


Fig. 3. Peak gain versus calculated total spontaneous current density (line) and experimental drive current (symbols) The calculated data reflects the fundamental lower limit for a device with an internal efficiency of 1000/o. The dotted line includes non-radiative recombination processes

References

1. D.P. Bour, D.W. Treat, R.L. Thornton, R.S. Geels and D.F. Welch, "Drift leakage current in AlGaInP quantum well **lasers"**, IEEE J. Quant Elec. 29 pp.13371343 (1993).

2. S.A. Wood, P.M. Smowton, C.H. Molloy, P. Blood, D.J. Somerford and C.C. Button, Appl. Phys. Lett. "Direct monitoring of thermally activated leakage current in AlGaInP laser diodes", 74 pp.2540-2542 (1999).

3. P. Blood, A.I. Kucharska, J.P. Jacobs and K. Griffiths, "Measurement and calculation of spontaneous recombination current and optical gain in GaAs-AlGaAs quantum well structures", J. Appl. Phys. 70, pp.1 144-1156 (1991).

4. W. W. Chow and S. W. Koch, *Semiconductor-Laser Fundamentals: Physics of the Gain Materials* (Springer Verlag, Berlin, 1999).

5. W. W. Chow, P. M. Smowton, P. Blood, A. Girndt, F. Jahnke and S. W. Koch, "Comparison of experimental and theoretical GaInP quantum well gain spectra", Appl. Phys. Lett. **71, pp. 157-159 (1997).**

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