21

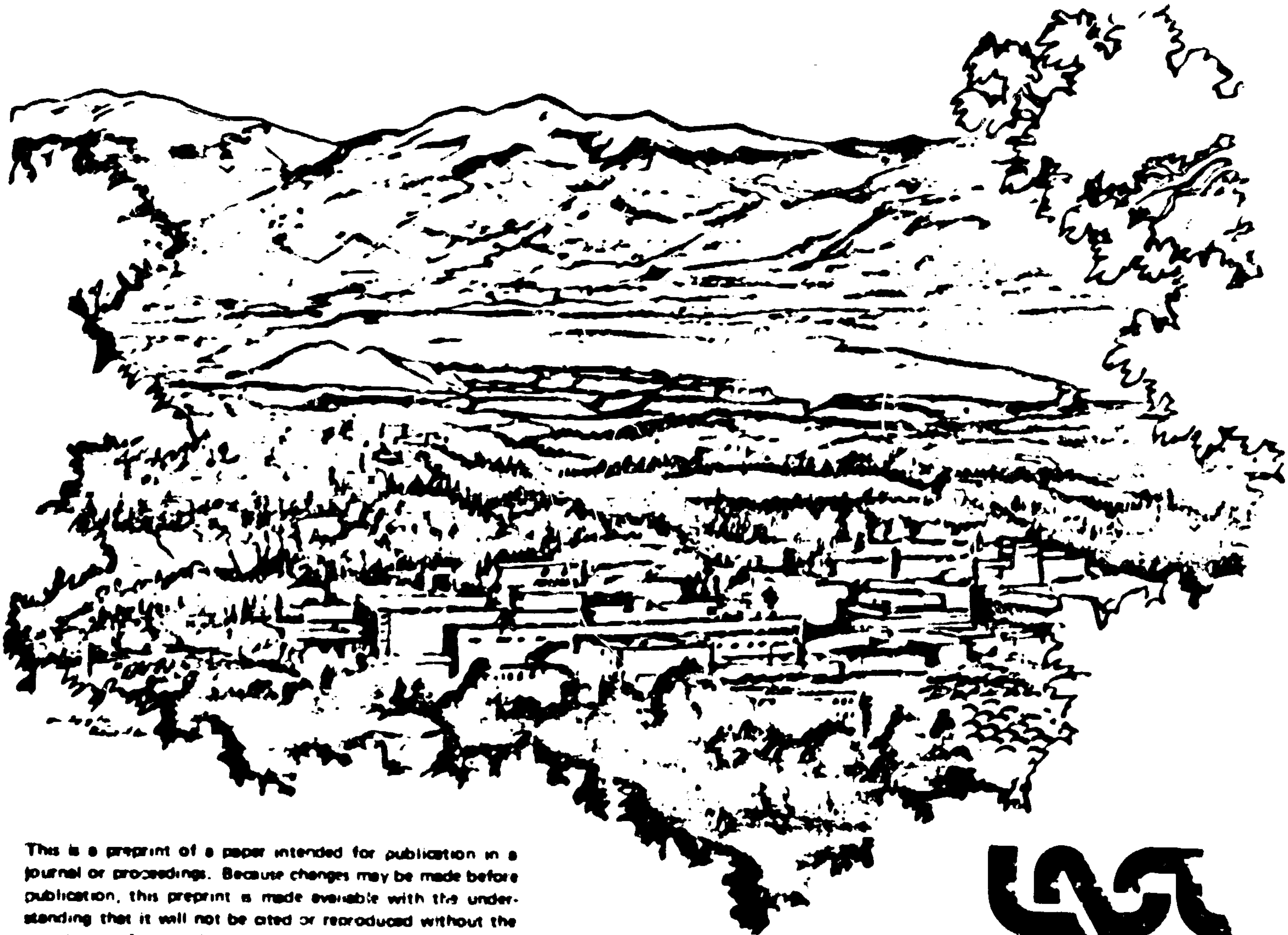
LA-UR 79-3308

PROGRESS REPORT FOR THE 1979 CECAM WORKSHOP ON "TRANSPORT OF FAST ELECTRONS IN LASER FUSION PLASMAS"

R. J. Mason

Proceedings of the 1979 CECAM Workshop on
Fast Electron Transport, Orsay, France
August 20 - September 14, 1979

MASTER



LASL
LOS ALAMOS SCIENTIFIC LABORATORY

PROGRESS REPORT FOR THE 1979 CECAM WORKSHOP ON "TRANSPORT OF FAST ELECTRONS IN LASER FUSION PLASMAS"

by

Rodney J. Mason
Los Alamos Scientific Laboratory, X-1
Los Alamos, NM 87545

At the conference my attention was attracted to three problem areas in laser-driven electron transport: (1) ion-acoustic turbulence as a source of inhibition, (2) the effects of $\bar{E} \cdot \bar{j}$ heating of the thermals, and (3) the possibility of thermal inhibition by thermal electron "runaway" or "trapping".

Ion-acoustic Turbulence

We alerted the workshop to the FKL^2 (Forslund, Kindel, Lindman, Lee) formula for the ion-acoustic effective collision rate

$$\nu_{(FKL^2)} = 3 \times 10^{-5}\left(\frac{m_c}{m_i}\right)^{1/4}\left(\frac{T_c}{T_i}\right)\frac{U_c}{(T_c/m)^{\frac{1}{2}}} \qquad \begin{matrix}(c = \text{cold electrons})\\ (T_i \simeq 0.1 \text{ keV})\end{matrix}$$

and determined with Prof. Haines and Dr. Colombant that this was about an order of magnitude below all prior rates, including that proposed by Biskamp et al. We submitted that in calculations with our Monte Carlo Hybrid transport model ν_{FKL^2} was at least 300 times too low to produce any significant inhibition of the suprathermal electron transport.

In subsequent investigations we have been reassured that the FKL^2 rate was obtained from PIC simulation of the maximum possible reliability, and that FKL^2 achieved a numerical noise rate far lower than in earlier simulations. FKL^2 also used a $U_c/(T_c/m)^{1/2}$ ratio of order 0.3 - more nearly characterizing laser driven return currents than the O(1) Biskamp rate. Nevertheless, a series of M.C. hybrid simulations were run using multiples of the ν_{FKL^2} rate. Below 10^2 ν_{FKL^2} the enhanced ion-acoustic turbulence has no effect on transport. At 3×10^2 ν_{FKL^2}, as the ion-acoustic effect became significant, it manifested itself as inhibition of <u>both</u> the thermal and the suprathermal components, i.e. when ν was large enough to give an $E \sim \nu j_h$ to stop the hots, ($h \equiv$ hot electrons), it also reduced the the thermal conductivity thru its appearance in $K \sim \frac{T^{3/2}}{\nu}$. Again in simulation, ion-acoustic turbulence, when significant, stops both the colds and the hots. The most modern experimental investigations find that <u>only</u> the thermals are strongly inhibited. This leads us to the conclusion that ion-acoustic turbulence fails as the mechanism for the observed inhibition.

<u>E·j heating</u>

One section of the workshop was concerned with better $\bar{E}\cdot\bar{j}$ modelling, principally in multi-group P_n and S_n codes. Our Monte Carlo model gives an altered perspective. In our hybrid scheme, described in a preprint PRL distributed at the meeting[1], the hot and cold velocities are calculated explicitly including the affects of inertia. The resultant j values are, therefore, unique [which is not the case under flux limited transport, where the arbitrary flux limit factor controls j]. Also, E comes uniquely from the plasma-period-dilation technique or our moment method[2] which fix it by establishing quasi-neutrality $j_h = -j_c$. The E·j thus derived is straightforward and specific.

Follow on calculations investigating the effects of $\bar{E}\cdot\bar{j}$ have shown that at plateau densities, i.e. the densities slightly above critical and just beneath the laser deposition surface, the $\bar{E}\cdot\bar{j}$ "ohmic heating" is dominant. The heating of the background plasma is, of course, responsible for the burnout of its resistivity and the subsequent penetration of the hot electrons into the previously cold thermals. Our simulations show that in this region from n_{crit} to 2.0 n_{crit} the burnout proceeds at 30 μm/ps in SiO_2, for example. The burnout continues at nearly this same rate when we turnoff a) the thermal conductivity, and b) the direct depositions from Coulomb drag. Finally, if $\bar{E}\cdot\bar{j}$ is ignored, the thermals remain cold, and for $T_c < 10$ eV the suprathermals would be classically inhibited. In practice, of course, all three mechanisms are active, heating and burning-out the thermals. The $\bar{E}\cdot\bar{j}$ heating alone is sufficient, however, so that, clearly, a precise estimate of its contributions must be included in valid calculations.

Thermal Electron Trapping

At the workshop Malcolm Haines indicated that he had been thinking that a breakdown of the Braginskii formalism might be responsible for the reduced transport in thermals. Specifically, that the E field driving the return current might preferentially grab the hottest, less collisional electrons ($\nu \sim 1/T^{3/2}$) and return them to the laser source region, eliminating their transport into the target depths. We had been thinking along somewhat similar lines - viewing such a process as a collisionless "trapping" of the heated thermals in the potential well associated with the field drawing the return current.

Investigating this trapping phenomena has become the current focus of our simultational efforts with the M.C. model. We have modified the model to allow for a group of <u>Monte Carlo thermals</u>. These are either initially present, or subsequently produced following the heating action of the laser. These newer simulations have shown that: in (a) inhomogeneous geometry - constant plateau density below the critical surface - the thermal transport at moderately high temperatures does, indeed, stream at the classical flux limit value. [This is supportive of our earlier hybrid work[2] which used a classical limit on the heat flux] (b) At large density gradient interfaces, with the thermals initially cold on the high density side, an E field develops which reflects a large fraction of the thermals incident from the low density, laser-driven side. They are effectively trapped by this field with their thermal conductivity correspondingly reduced. This trapping result is, however, very new, and may change as the calculations are refined.

I am grateful to Dr. Carl Moser for his kind hospitality during my visit to France, to my conference coworkers for stimulating discussions, and also to CECAM for its use of the facilities and its support.

References

1. R. J. Mason, "Monte-Carlo Hybrid Suprathermal Electron Transport", submitted to PRL July 1979.
2. R. J. Mason, "Electron Transport in Laser Fusion Targets", in Proc. of the 5th Workshop on Laser Interaction With Matter", Nov. 5-9, 1979 Rochester, NY, Plenum Press, to be published.