WS101-6: Development of intense, pulsed ion beams for studies of defect dynamics and materials processing very far from equilibrium

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We use the BELLA petawatt laser [1] to accelerate ions to multi-MeV energies at a repetition rate of up to 1 Hz [2]. Ion acceleration is now routinely conducted at BELLA in parallel to the main program on laser-plasma acceleration of electrons. With laser intensities in the 1019 W/cm2 regime at our current beamline, we find ion intensities up to 1012 ions/shot with low divergence and peak proton energies of ~7 MeV. When transported to a second target, ion pulses can then drive the formation and annealing dynamics of defects [3] and simulations predict that they can uniformly heat materials to temperatures of >1 eV, well into the warm dense matter regime [4]. For lower ion energies and intensities, we operate an induction linac (NDCX-II, [5]), which delivers 2 to 10 ns long pulses of ~1011 protons or helium ions at 1 MeV into a few mm2 spots at a repetition rate of ~1/min. Ion intensities can be selected for materials processing, to form desired defect structures or to drive desired phase-transitions. We present results from ion acceleration and materials processing experiments and simulations [2, 4, 5]. We then discuss the status and prospects for some specific near-term applications e. g. in color center synthesis for spin qubits in diamond [6] as well as the implementation of a short focal length beamline for laser intensities >1021 W/cm2 and the quest for much higher proton energies (>100 MeV).

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