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Abstract: We discuss the status of the NIF ARC, an 8-beam 10-kJ class high-energy petawatt laser, and the future upgrade path of this and similar systems to 100-kJ-class with coherent phasing of multiple apertures.

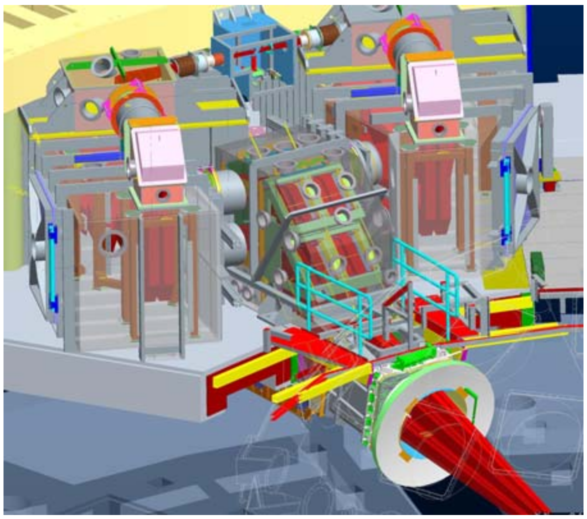

Figure 1: The ARC on NIF. The four split-beam pairs of the ARC Quad, with ~10-kJ total energy are temporally compressed in two vacuum vessels containing four independent four-grating compressors each. All eight beams are directed with independent pointing and timing adjustments to a volume about the NIF target chamber center.

The output pulse energy from a single-aperture high-energy laser amplifier (e.g. fusion lasers such as NIF and LMJ) are critically limited by a number of factors including optical damage, which places an upper bound on the operating fluence; parasitic gain, which limits together with manufacturing costs the maximum aperture size to ~40-cm; non-linear phase effects which limits the peak intensity in the amplifier; and the physical size (which limits the duration of the pulse before compression) and damage fluence and aperture of diffraction gratings in the pulse compressor. For example, the Advanced Radiographic Capability (ARC) project at NIF is designed to provide up to 13-kJ from one quad of NIF beams, with peak focused intensity above 10^{19} W/cm^2. The ARC uses a novel short-pulse fiber laser front end to provide few-ns duration stretched pulses, synchronized to the NIF laser chain with picosecond accuracy, for injection into four of the NIF's 192 amplifier lines. The output of this system will initially be used for multi-frame hard x-ray radiography of imploding NIF capsules during the National Ignition Campaign, where the independently targetable and timeable pulses provide for upto eight spatially separated x-ray sources. In addition, the full ARC Quad will be used as the high-intensity short-pulse driver for fast ignition studies, where the eight ARC beams will be synchronously timed and focused to a common point at the tip of a cone target.

Future applications, such as full-scale fast ignition on the NIF and high-energy density physics, will require extraction of >10x greater output energies than currently achievable with the ARC Quad (see Figure 2). While the use of multiple incoherently-added ARC quads is a simple route forward, both high peak-intensity and long stand-off applications (e.g. inertial fusion power generation), extraction from a coherent aperture is needed. Using such a high-energy petawatt (HEPW) beamline as a modular unit, we will discuss large-scale architectures for coherently combining multiple HEPW pulses from independent apertures, called CAPE (Coherent Addition of Pulse Energy), to significantly increase the peak achievable focused intensity.

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Figure 2: The proposed five-quad geometry to be used for full-scale fast-igntion on the NIF.

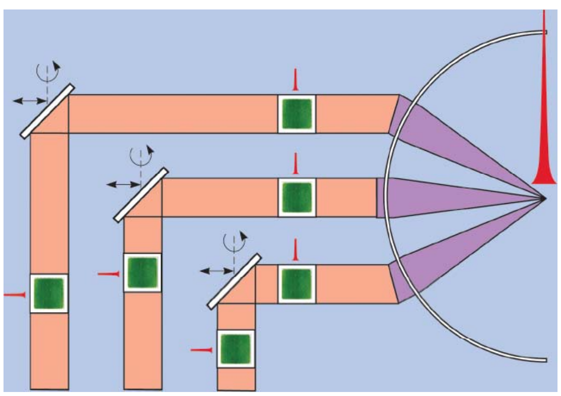

Figure 3: The CAPE geometry. Pulses output from independent amplifiers (with a common seed) are rephased to coherently add in their common focal plane. The peak intensity scales quadratically with the number of apertures.

Importantly, the maximum intensity achievable with CAPE increases non-linearly. Clearly, the total integrated energy grows linearly with the number of apertures N used. However, as CAPE combines beams in the focal plane by increasing the angular convergence to focus (i.e. the f-number decreases, see Fig. 3), the focal spot diameter scales inversely with N. Hence the peak intensity scales as N^2.

Lastly, an important feature of this architecture is the ability to coherently combine beams to produce complex spatio-temporal intensity distributions for high energy density science applications such as fast ignition and laser-based accelerators.

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