12 CONCLUSIONS

As a result of this research we obtained an invaluable experience and outcomes, which might affect the future of the X-Ray Free Electron Lasers.

The procedure and result of the High Gain Harmonic Generation Experiment has been presented.

The properties of the Self Amplified Spontaneous Emission produced by the radiator have been measured. We measured 50-200 pJ of energy. The spectrum width of the radiation wavelength (FWHM) was measured using a multi shot technique as 150 nm. We observed a gain of 10-70 over the spontaneous radiation by a charge scan technique.

The measured HGHG output was between 20 and 100 μJ of energy which is about factor ~10^6 times larger than the SASE case and about ~10^7 times larger than the spontaneous radiation.

The significance of this technique is that the radiation produced by the FEL process carries the properties of the seed laser. The central wavelength is determined by the seed laser, not by the energy of the electrons, which may be less stable. With HGHG procedure the FEL pulse length can be controlled by the seed laser therefore it is possible to produce FEL much shorter than the electron beam.

The multi-shot and single-shot spectrum measurements have confirmed that the spectrum of the HGHG output is 15 nm, which is narrower than SASE spectrum by an order of magnitude.

The transverse profile of the HGHG output, which has been observed by the pyroviewer infrared camera, indicates a good transverse coherence.

Two techniques have been used to measure the pulse length of the HGHG beam. The first one is the autocorrelator technique, which uses a doubling crystal to measure the pulse length. The other method is the Michelson interferometer. The difference between the techniques is while the autocorrelator measures the intensity pulse length, the Michelson interferometer measures the coherence length. The measurements showed that

two methods are in good agreement. Thus longitudinally the HGHG beam is practically fully coherent.

The second and the third harmonics of the fundamental radiation (5.3 μm) were measured. Their dependence with the modulation, which shows the strength of the FEL interaction, has been examined. We observed a strong correlation with the theoretical simulations. We also observed a strong indication of saturation or near saturation conditions due to rapid growth of the higher harmonics.

Finally, we studied the steering effect of the electron beam on the HGHG output. We steered the electron beam in the radiator wiggler and observed that the HGHG output follows the electron beam. This measurement may have importance when we want to cascade the HGHG process to the X-Ray regime. In that case we will need several HGHG sections. The output of one section will be used as the seed laser for the next section. Thus it would be convenient to be able steer the output radiation with the electron beam for the alignment of the next section.

This work has been supported by Office of Naval Research Grant no. N00014-97-1-0845 , U.S. Department of Energy, Office of Basic Energy Sciences, under Contracts Nos. DE-AC02-98CH10886 and W-31-109-ENG-3.