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A Next Generation Ultra Short Pulse Reflectometer

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Ultrashort Pulse Reflectometry (USPR) is a diagnostic technique involving the propagation of a number of ultra short duration (~few nsec) chirps which contain frequency components spanning large portions of the desired plasma density profile [1]. Here, each frequency component in the wave packet reflects from a different density layer in the edge plasma. The reflected wave packet is down-converted and passed through a multichannel filter bank where it is detected, with time-of-flight measurements made on each of the filtered wave packets. With sufficient time-of-flight (TOF) data, it is then possible to reconstruct the electron density profile of the target plasma.

One key advantage of USPR is that the diagnostic measurement takes place during such a short time (~nsec) that density fluctuations are essentially frozen in place. This technique was applied in the past to the Sustained Spheromak Physics Experiment (SSPX), where a 24-channel system operated spanning a frequency range of 33 to 75 GHz [2]. UC Davis is now extending this technique with higher power (>10X) sources, enhanced channel count (~60), and higher speed TOF electronics.

A schematic illustration of this next generation USPR system is illustrated in Fig. 1. A microwave chirp is upconverted to mm-wave frequencies by high power active multiplier chains (AMCs); three AMCs provide coverage extending from 26.5 to 75 GHz. The reflected waves are collected by the same microwave horns (i.e., a monostatic horn configuration), and down-converted to microwave frequencies (2.55 to 18.5 GHz). TOF data are collected by a field programmable gate array (FPGA) based controller which will collect and process all USPR data in addition to generating all required control signals.

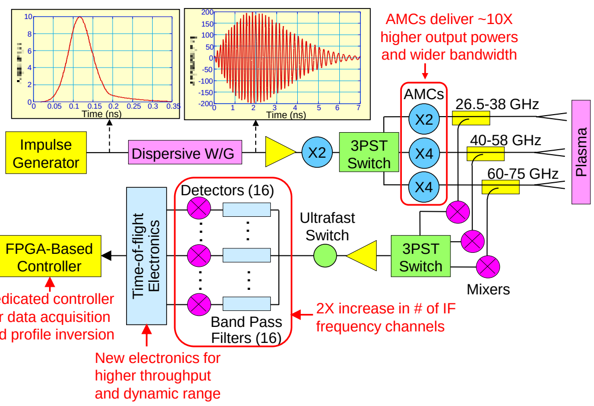

Fig. 1. Illustration of the USPR technique, showing advances over the previous USPR implementation on the SSPX device.

Output from a Picosecond Pulse Labs 3500C impulse generator is dispersed into a monotonically decreasing frequency chirp using a length of WRD475 waveguide, and high pass filtered to form a 5.0 to 9.5 GHz chirp. This low frequency chirp is amplified, frequency doubled, and amplified once more to form a 10.0 to 19.0 GHz Baseband Transmitter Chirp which is then upconverted to mm-wave frequencies (see Fig. 2). An SP3T switch connects this chirp to one of three waveguide assemblies, while a similar switch connects the USPR receiver to the same assembly. With a pulse repetition rate of 1 MHz, electron density profiles may be obtained in as little as 3 μsec.

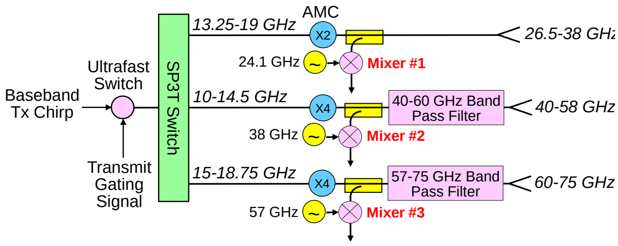

Fig. 2. Schematic diagram of the USPR mm-wave configuration.

Work is now underway on the critical TOF electronics, which is illustrated schematically in Fig. 3. The input signal is amplified, rectified by a high speed detector, and amplified once more before passing through a Constant Fraction Discriminator (CFD) which generates a trigger signal whenever the input signal exceeds the detection threshold limit. A high speed flip-flop generates a pulse that in turn charges up a capacitor whose voltage is proportional to the length of the pulse. This is amplified, sampled by a high speed sample-and-hold (S/H), and finally digitized by the FPGA.

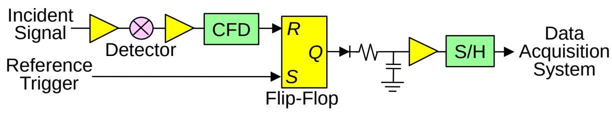

Fig. 3. Schematic layout of the time-of-flight circuit to be used by USPR.

The prototype TOF circuitry is scheduled to be completed by late August, and the entire system as illustrated in Fig. 1 by early October. Detailed descriptions of the USPR system, along with laboratory characterization results, will be presented.

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References

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