

# Academic publications on use of Keysight Technologies high-speed digitizers

## White Paper

### Overview

In laboratories around the world, Keysight Technologies instrumentation has become an integral part of advanced experimental systems, whether for system control or experiment observation. Applications include astrophysics, nuclear physics, particle physics, plasma physics, and other high-energy physics advanced research applications. Keysight high-speed instruments are used in two major areas, real-time control and measurement, and Single-shot, or event-based measurements. Expanding knowledge on phenomena at galactic or nanometer scale, confidence in results is strengthened by dependable measurement solutions that provide exceptional speed and measurement fidelity. Keysight provides the extreme speed and precision needed for system monitoring and control, and for capturing data from the events at speeds that exceed the interactions of the experiments themselves. A large amount of scientific material has been developed by users of our high-speed digitizers that are in the public domain. The following links will provide you with a wide range of data on where and how Keysight High-Speed digitizers are used in the expansion of scientific knowledge. A general overview can be found at <http://cp.literature.keysight.com/litweb/pdf/5990-5420EN.pdf>

This looks at single-shot and real-time experiments in, amongst other applications, particle acceleration, and radio astronomy.

## 1 Particle accelerator experiments

**Particle accelerators** may be circular or linear, and can measure from 1m to 10's of km in length. They are used as experimental sites for nuclear physics interactions, particle colliders and light sources (X-ray). Keysight digitizers are used in beam control – helping optimize the position of the beam through the steering and acceleration stages – and in the experiments that observe the particle and light interactions.

Scientific paper (Proceedings of EPAC 2006, Edinburgh, Scotland):

### **Fast Beam Dynamics Investigation Based on an ADC Filling Pattern Measurement**

A diagnostic tool to determine the longitudinal particle filling pattern was installed at the 1.5 GeV electron storage ring Delta, in Dortmund, Germany. This uses an Keysight Acqiris U1068A high-speed digitizer in an EPICS environment for data capture of the summed charge from a beam position monitor.

<http://epaper.kek.jp/e06/PAPERS/TUPCH018.PDF>

Scientific Paper (Proceedings of DIPAC 2005, Lyon, France):

### **Beam Diagnostic Devices and Data Acquisition for the HICAT Facility**

This paper describes the development of LINAC Beam diagnostics in the Heavy Ion Cancer Therapy facility (HICAT) at the university hospital in Heidelberg. This computer controlled system uses a combination of techniques to allow an automated detection of all relevant beam parameters.

[http://www-bd.gsi.de/uploads/paper/dipac05\\_peters.pdf](http://www-bd.gsi.de/uploads/paper/dipac05_peters.pdf)

Scientific Paper (Proceedings of PAC07, Albuquerque, New Mexico, USA):

### **High Power Tests of Normal Conducting Single-Cell Structures**

This paper describes the results of the first high power tests of single-cell traveling-wave and standing-wave structures, to determine the gradient potential of normal-conducting rf-powered particle beam accelerators. The tests were powered by SLAC's XL-4 klystron, and used an Keysight high-speed digitizer for measurement of high-power RF-signals.

<http://accelconf.web.cern.ch/Accelconf/p07/PAPERS/WEPMS039.PDF>

Scientific Paper (Proceedings of PAC05, Knoxville, TN, USA):

### **An Induction Linac Test Stand**

This paper describes the development of a single-cell test stand the Lawrence Livermore National Lab for studies aimed at improving the performance of its FXR radiographic facility. The Test Stand was used to calibrate voltage and current sensors and has ushered in a new era of Best Practices in precision rf measurements at FXR, such as time domain reflectometry (TDR) analysis of cell transmission element matching. The FXR uses 128 channels of Keysight high-speed digitizers that are implemented on the accelerator.

<https://e-reports-ext.llnl.gov/pdf/320299.pdf>

Scientific Paper (Poster presentation from ICALEPS 2011, Grenoble, France):

### **NSLS-II Filling Pattern Measurement**

This poster describes the High bandwidth diagnostic beam monitors that use Keysight high-speed digitizers to measure bunch-by-bunch charge variations at National Synchrotron Light Source II, Brookhaven National Lab.

[http://www.esrf.eu/icaleps2011/posters/wepkn014\\_poster.pdf](http://www.esrf.eu/icaleps2011/posters/wepkn014_poster.pdf)

## 2 Tokamak and stellarator plasma physics

**Plasma fusion** reactors will use Tokamak's as a key technology for future power generation systems. Tokamak fusion experiments look to stabilize plasma so that fusion reactions can occur (similar to those on the Sun) and Fusion reactors can be built. These Fusion reactors promise to provide "Clean" nuclear energy, and many projects are occurring today. Often linked to the ITER project (<http://www.iter.org/>) that links Europe, China, India, Japan, Korea, Russia and the US in a global investment for Fusion research.

Scientific Paper (AIP Review of Scientific Instruments, 82, 103501, 2011):

### **Edge and Core Thomson Scattering Systems and their Calibration on the ASDEX Upgrade Tokamak**

Thompson scattering is used for the measurement of radial profiles of electron density and temperature at the plasma edge. At the Max-Planck Institute für Plasmaphysik, these measurements are made using a number of Keysight high-speed digitizers.

<http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=RSINAK000082000010103501000001&idtype=cvips&doi=10.1063/1.3643771&prog=normal>

Scientific Paper (AIP Review of Scientific Instruments, 80, 103504, 2009):

### **Development and Testing of a Fast Fourier Transform High Dynamic-Range Spectral Diagnostics for Millimeter Wave Characterization**

This paper describes the use of a fast Fourier transform (FFT) based wide range millimeter wave diagnostics system for spectral characterization of scattered millimeter waves in plasmas. It has been successfully brought into operation. The scattered millimeter waves are heterodyne downconverted and directly digitized using an Keysight Acqiris U1065A high-speed digitizer.

<http://www.mate.tue.nl/mate/pdfs/11348.pdf>

Scientific Papers (IEEE Transactions on Nuclear Science, Vol. 58, No. 4, August 2011, and Publication of the UKAEA):

### **Real Time Operation of MAST Thomson Scattering Diagnostic**

The Mega Ampere Spherical Tokamak (MAST) in the UK, which is one of the larger Tokamak sites and a precursor for the ITER project. Keysight high-speed digitizers are used for the data acquisition in Thompson scattering for electron temperature measurement.

<http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05771579>

### **Timing and Data Acquisition System for MAST High Rate Thomson Scattering**

This paper describes the use of Keysight Acqiris high speed digitizers in the Thomson scattering instrumentation.

<http://www.ccf.ac.uk/assets/Documents/UKAEA-FUS-520FINAL.pdf>

Scientific Paper (Proceedings Seventh IAEATEchnical Meeting on Control, Data Acquisition, and Remote Participation for Fusion Research 2009):

### **New Data Acquisition System for the Ultra Fast Sweep Reflectometers of Tore Supra**

The French Tokamak Tore Supra is one of the biggest tokamaks in the world, and holds the record for the longest plasma duration time. This poster describes its upgrade to use multiple Keysight Acqiris high-speed digitizers.

<http://www-fusion-magnetique.cea.fr/miaea2009/website/data/articles/000100.pdf>

### 3 X-, Z-pinch, and inertial confinement plasma physics

**Inertial confinement** is a technique used for fusion research to stabilize a plasma and in-so-doing generate cleaner nuclear energy with the same processes that power our own sun. Major research centers include Megajoule in France (LMJ), NIF at Lawrence Livermore National Lab, and the Z-Machine at Sandia National Lab in the US.

Scientific Papers (from IEEE and IEEE Transactions on Dielectrics and Electrical Insulation Vol. 18, No. 4; August 2011):

#### **A Durable, Repetitively Pulsed, 200 kV, 4.5 kA, 300 ns Solid State Pulsed Power System**

<http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05958284>

#### **A Durable Gigawatt Class Solid State Pulsed Power System**

<http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05976117>

Both of these papers describe a solid-state system for delivery of high-energy electron beam pulses to drive a KrF laser for inertial fusion. For measurements of the system durability, a Keysight Acqiris digitizer was used at 1 GSa/s to capture every shot, and then every 100th shot of the output pulses.

Scientific Papers (Nature 434, 1115-1117, 28 April 2005):

#### **Observation of Nuclear Fusion Driven by a Pyroelectric Crystal**

Here, research into room-temperature fusion is presented, that uses the heating a pyroelectric crystal in a deuterated atmosphere can generate fusion under desktop conditions. The system uses two Keysight Acqiris high-speed digitizers in the detector arrangement, configured as an 8-channel digitizer.

<http://www.nature.com/nature/journal/v434/n7037/full/nature03575.html>

### 4 Environmental research

**Environmental research** investigates the ground, air, and water around us to help us understand our own, and even extra-terrestrial environment. Remote sensing techniques are often used, that use Keysight high-speed digitizers to allow probing, measurement and chemical analysis of the material around us.

Scientific Paper (IEEE Transactions on Geoscience and Remote Sensing, Vol. 47, No. 7, July 2009):

#### **Intercomparison of Digital Fast Fourier Transform and Acousto-Optical Spectrometers for Microwave Radiometry of the Atmosphere**

This paper presents measurements of atmospheric trace constituents using digital FFT spectrometers, built around Keysight Acqiris high-speed digitizers, and compares the results with alternative measurements. The resulting FFT spectrometer is superior in resolution and system stability as well as in the linearity and stability of the frequency axis.

<http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=04813231>

### 5 Astronomy

**Astronomy and astrophysics** labs use high-speed digitizers for the capture of data. Experiments include observation of fast gamma radiation through secondary (Cherenkov) light, that requires multichannel coincidence measurements, or RF/uv recording as a function of time.

Scientific Paper (Proceedings of 2011 Fermi Symposium, Rome, May 9-12):

#### **Multiwavelength Study of TeV Blazar Mrk421 During Giant Flare and Observations of TeV AGNs with HAGAR**

The High Altitude Gamma Ray (HAGAR) telescope is run by the Indian Institute of Astrophysics. It is an Atmospheric Cerenkov experiment with 7 telescopes each with a UV sensitive photo-multiplier tube (PMT). This paper describes the use of this arrangement, which also includes Keysight Acqiris high-speed digitizers for observation of Cherenkov light from TeV gamma-ray-emitting blazars, and a radio galaxy.

[http://arxiv.org/PS\\_cache/arxiv/pdf/1110/1110.6795v1.pdf](http://arxiv.org/PS_cache/arxiv/pdf/1110/1110.6795v1.pdf)

Scientific Paper (Proceedings of ICRC 2001):

#### **The Status of the STACEE Observatory**

The Solar Tower Atmospheric Cherenkov Effect Experiment (STACEE) is a ground-based instrument designed to study astrophysical sources of gamma radiation in the energy range of 50 to 500 GeV, and is located at the National Solar Thermal Test Facility in Albuquerque, New Mexico, USA. This paper describes the construction and commissioning of the site including 64 heliostat mirrors each with a dedicated photo-multiplier tube (PMT) and Keysight Acqiris high-speed digitizer.

[http://arxiv.org/PS\\_cache/astro-ph/pdf/0107/0107427v1.pdf](http://arxiv.org/PS_cache/astro-ph/pdf/0107/0107427v1.pdf)

<http://www.nature.com/nature/journal/v434/n7037/full/nature03575.html>

Scientific Papers (Astronomy and Astrophysics, Volume 442, Issue 2, November 1 2005, pp.767-773):

#### **A Broadband FFT Spectrometer for Radio and Millimeter Astronomy**

The ARGOS FFT radio spectrometer used to detect and to measure molecular lines ubiquitous in star forming regions, planetary and cometary atmospheres. At its heart is a real-time Fast Fourier Transform (FFT) embedded into the FPGA of an Keysight Acqiris high-speed digitizer running at 2 GB/s. This paper describes the implementation of this device, and measurements made at the KOSMA telescope.

[http://arxiv.org/PS\\_cache/astro-ph/pdf/0509/0509671v1.pdf](http://arxiv.org/PS_cache/astro-ph/pdf/0509/0509671v1.pdf)

Scientific Paper (Proceedings URSI General Assembly, Chicago, 2008 August 12):

#### **Atmospheric Phase Correction for Submillimeter Interferometry using Stratospheric Ozone Line Emission**

This paper from the Smithsonian Astrophysical Observatory, describes a new approach to estimating the line-of-sight water vapor column by monitoring stratospheric ozone emission lines. The variability in this water vapor in the troposphere limits the performance of many radio interferometers used in astronomical applications.

<http://www.ursi.org/proceedings/procGA08/papers/J03bp6.pdf>

This collection of papers shows just some of the many experiments around the world that are enabled with Keysight high-speed digitizers.

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