Case Study

Application	*Physics – Quantum Research*
Product	*M4i.6631-x8 AWG* *2 Channel 1.25 GS/s 16 Bit*

Arbitrary Waveform Generator precise enough for quantum research

Precision is always important in research and there can be few research areas needing greater precision than that of quantum research. The Institute for Quantum Optics and Quantum Information at the University of Innsbruck, Austria needed an Arbitrary Waveform Generator (AWG) to generate a wide variety of signals for their research.

Radio Frequency Regime

The first application is applying a multiple-frequency signal in the radio frequency regime. Each frequency component is realised using a sinusoidal function. The resulting beat signal is used to simultaneously address individual ions in a trapped-ion quantum simulator. The ion trap is shown in figures 1 and 4.

Christine Maier, a researcher at the Institute, explains, "We are doing the quantum simulation with trapped, cooled calcium ions, for which single-ion addressability is essential. To achieve this, we send a laser beam through an acousto-optic deflector (AOD). The frequency of the radio frequency signal, which one applies to this AOD crystal, defines the deflection angle of the laser beam and therewith it decides which ion of our linear ion string (Figure 2) is addressed. The AWG now allows us to produce multiple-frequency signals, even with each having arbitrary amplitudes, which means that we can now address multiple ions in our ion string simultaneously. One advantage of this is that the experiment is faster because we don't need to cycle through addressing each ion individually, one after the other.

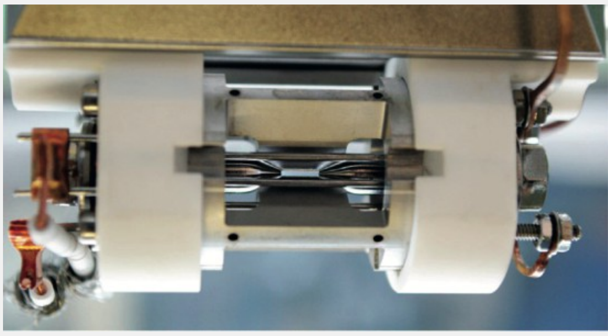
Figure 1 Ion trap

But it also opens up an entirely new field of study for us: up to now we could only investigate unperturbed energy transport in our ion chain. However, by addressing individual ions with arbitrary strength means that we now can create arbitrary potential barriers and study energy transport in disordered quantum systems. The AWG even allows us to program time-varying potentials to study dynamic disorder phenomena."

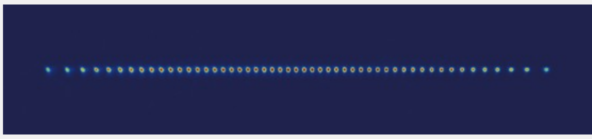
Figure 2 Ion string

Destructive Interference

The second application is the cancellation, via destructive interference, of undesired frequency mixing terms that arise, for example, when applying multiple-frequency signals to an acousto-optic modulator. "Applying RF signals to acousto-optic crystals is a basic technique in our laboratories," she adds. "When applying multiple-frequency signals, several sum- and difference- frequency components will arise and finally map onto the optical signal that you are sending onto the ions. This brings two problems. First, you lose power from the frequency components that you actually want and second, the mixing terms could hit some resonance


Figure 3 The laboratory set up

frequencies of the ion chain and destroy the quantum model that you want to simulate. Using the AWG enables us to cancel these undesired terms via destructive interference in real-time measurement and feedback loops."

Because of the variety of applications, it was important to have an AWG that is easy to program using a PC so that the output could be easily customised to each use. A Spectrum M4i.6631-x8 as shown in figure 5 was selected because, being on a PCI Express card, it could be incorporated into the PC and directly driven by it.

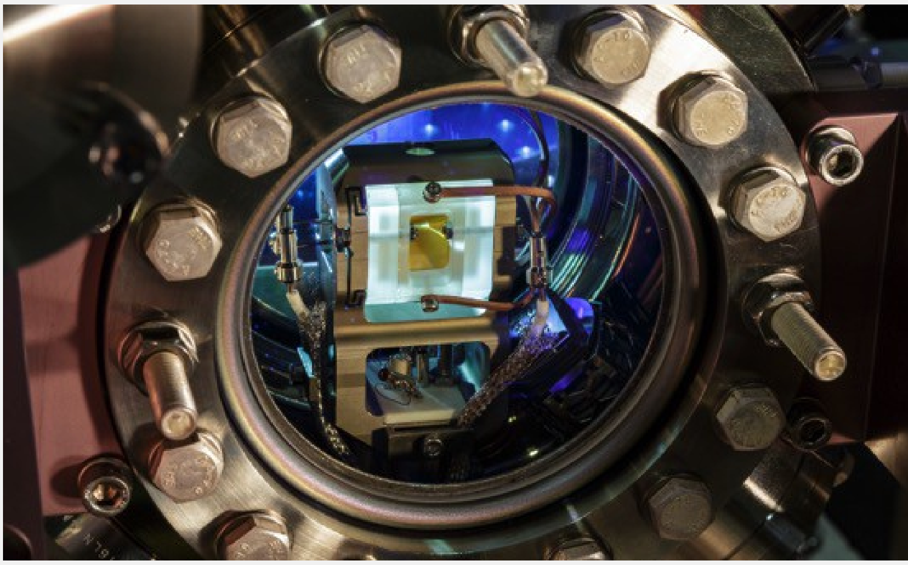

Figure 4 Ion trap

Used AWG M4i.6631-x8

"It is highly configurable," adds Maier. "Two AWG channels, a choice of trigger options, external clock inputs, multiple and gated replay modes, looping functions, and even the possibility to combine two trigger inputs via logic gates. This combined with the high resolution and a sampling rate of 1.25 GS/s made it the logical choice to provide the flexibility for the projects that we have now and, importantly, whatever needs we may have in the future with just one instrument."

The Spectrum AWG can replay loaded waveforms from its 4 GB of internal memory at speeds of up to 1.25 GS/s. The digital signal is converted into an analog output signal with a defined offset and amplitude using 16-bit D to A conversion to provide fine signal details that emulate those found in the real world. Any waveform can be replayed from a previously acquired waveform to a calculated or simulated waveform from DC to 400 MHz. It has a unique FIFO streaming capability that enables it to generate arbitrary waveforms for hours at a time unlike other AWGs that have reduced signal play times due to limited on-board memory. This enables tests to be carried out for much longer periods.

Figure 5 Spectrum's M4i.6631-x8 AWG

Further information can be found at
http://spectrum-instrumentation.com/en/multi-channel-awg-da-arbitrary-waveform-generators-overview