

An optimized optical delay line with temperature compensation

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The poster shows the design and development of a low-loss, low-latency optical delay line that provides temperature stability within a given temperature range. Such delays are of particular interest for stochastic cooling systems, where they are used to synchronize a system's correction pulse and in a feedforward loop of optical comb filters. However, commercially available optical delay lines have certain disadvantages for stochastic cooling - large intrinsic delay, high and non-constant optical attenuation, and overall delay drift due to temperature-dependent optical fibers. To mitigate these problems, an optimized optical delay line has been developed for the stochastic cooling systems of the COSY (FZ Jülich, Germany) and HESR (FAIR, Germany) accelerator facilities

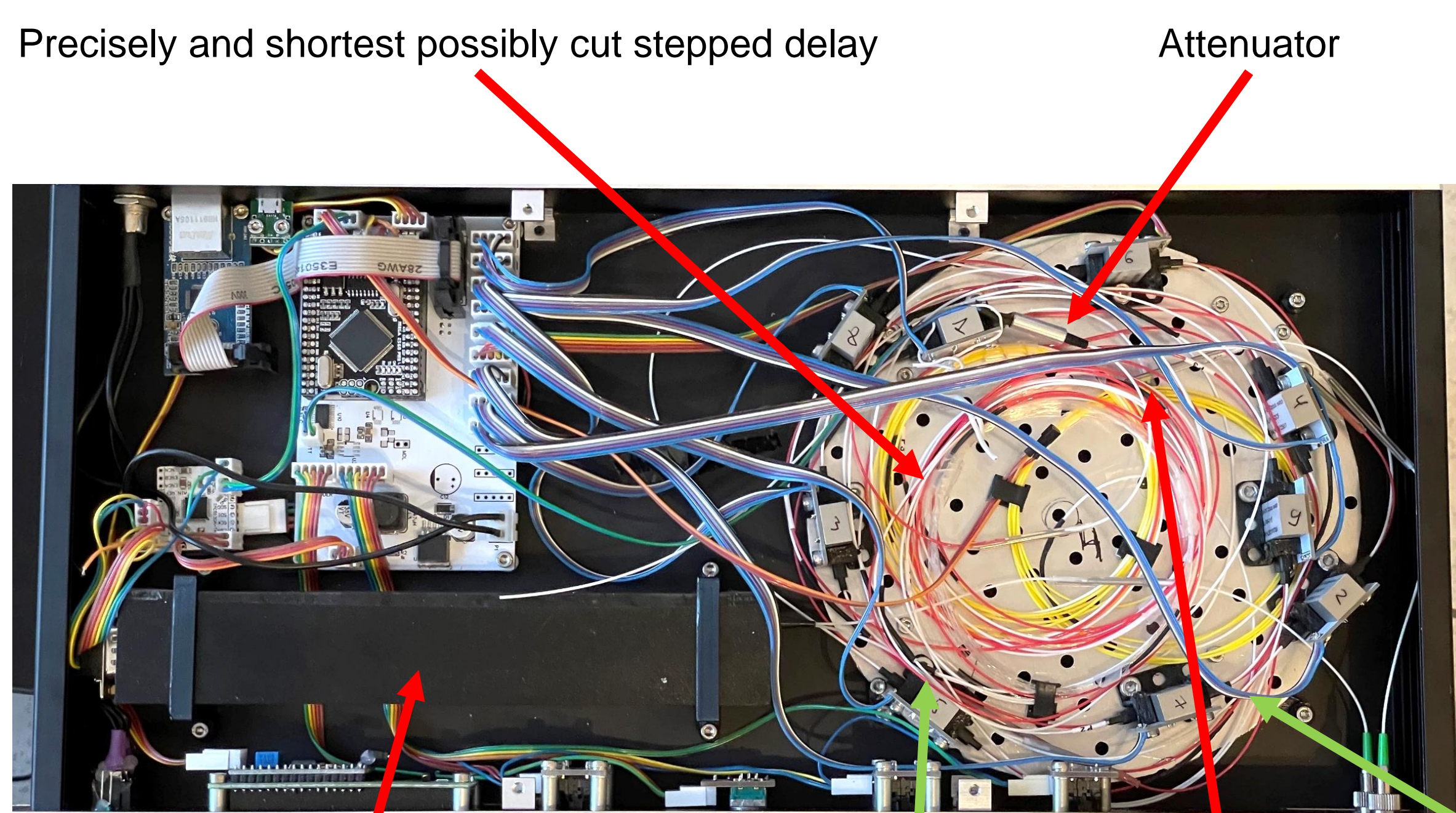
Motivation:

- No commercially available optical delays with large delay range and small resolution, only separate stepped and motorized precise delays
- Attenuation varies when switched to a different state
- Temperature dependence of stepped delays (SMF $\sim 40\text{ps/km/K}$ or $>1\text{ps/K}$ for a typical delay)
- Commercially available devices usually provide large intrinsic delay and/or large insertion losses

As a result, when used in stochastic cooling systems (system and comb filter delays), it is required to re-adjust the parameters during the day and after every step change in stepped delay.

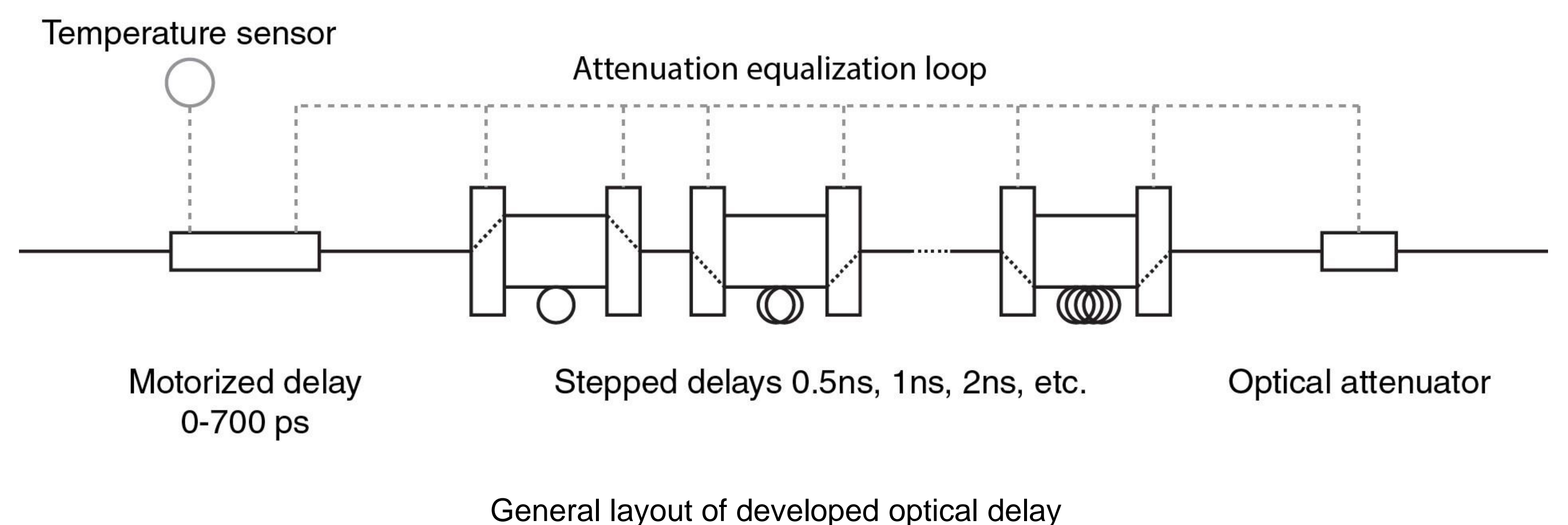


Optical delay 0-128ns (OPDM-128)



Precisely and shortest possibly cut stepped delay

Attenuator

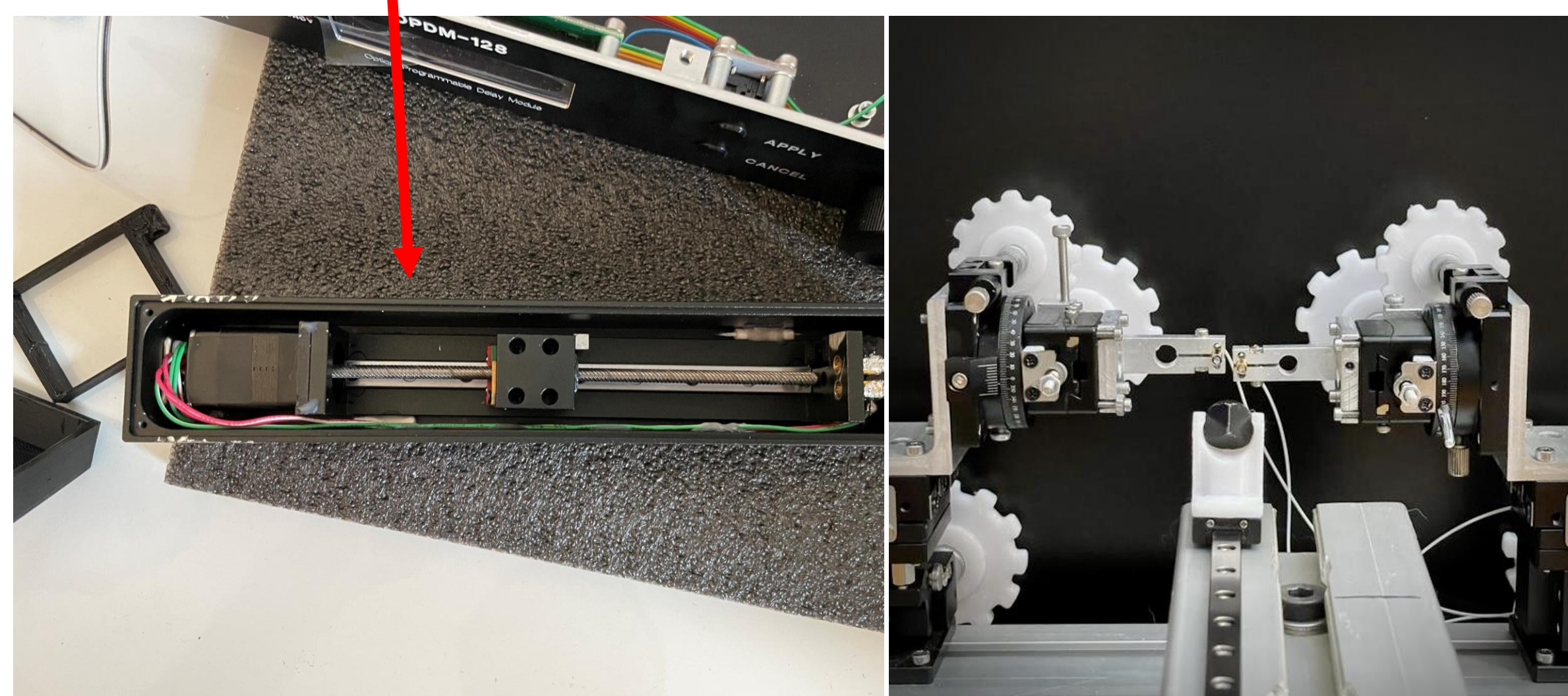


Precise motorized optical delay (left)

Temperature sensor

Optical 1x2 switches for stepped delay, cherry-picked to have smallest possible insertion losses

At higher steps a phase-stabilized optical fiber (yellow) is used to mitigate temperature dependence

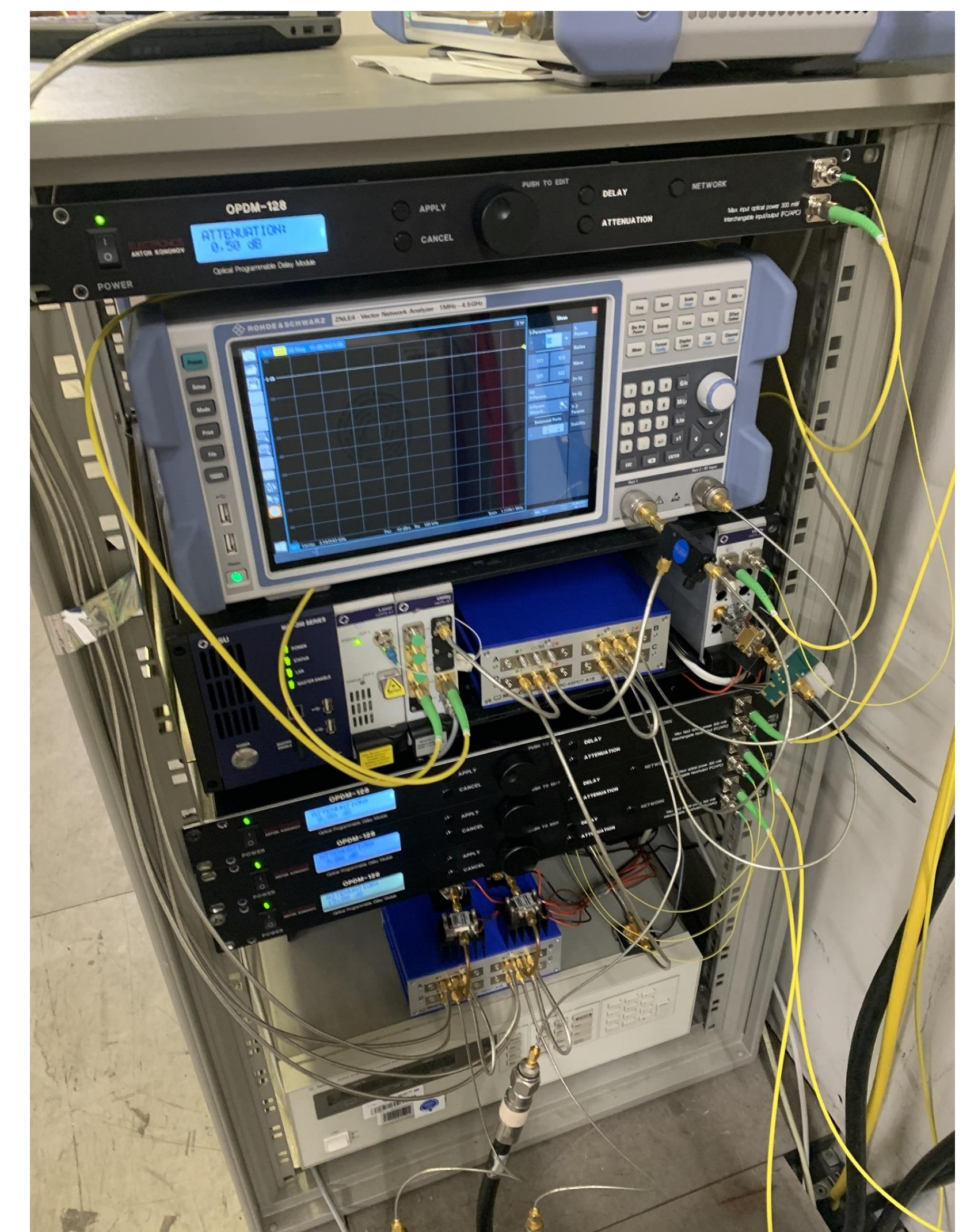


Opened motorized optical delay (left) and alignment tool, created to adjust input and output fibers in the delay

Relevant parameters:

Optical delay range	0 to 128 ns
Optical delay resolution	± 0.001 ps
Optical delay accuracy	± 0.01 ps
Optical delay repeatability	± 0.01 ps
Latency (own delay)	< 14 ns
Insertion loss	< 5.5 dB
Insertion loss variation	± 0.1 dB
Operating temperature	10 °C to 40 °C

4 developed optical delays used at COSY accelerator as system and filter delays:



Summary:

Developed optical delays provide precise optical signal delay in range 0 to 128 ns with 1 fs resolution. The instrument has low optical insertion loss and reduced delay latency of less than 14 ns. A unique feature of the instrument is an internal equalization of delay and attenuation. Together with temperature compensation of the delay it results in nearly constant insertion loss and delay accuracy over the whole delay and temperature ranges