Sagnac interferometers for gravitational wave detection

From small-scale experiments to large-scale detectors

Sagnac-based low-frequency detectors

Quantum noise plays a dominant role as limiting noise source in conventional Michelson interferometers, in the form of quantum back-action noise.

As was shown theoretically, Sagnac speed-meters are a prospective alternative to Michelson-based configurations. The Sagnac topology exhibits significantly less quantum noise at low frequencies than comparable Michelson-based interferometers and thus outperforms these with respect to better low-frequency sensitivity. However, research and development will be necessary to bring the Sagnac topology to the required level of maturity.

From prototypes to full-scale detectors

One of the challenges in the transition to the Sagnac topology in GW detectors is to catch up with more than four decades of experience with Michelson interferometers.

The ERC-funded proof-of-principle speed-meter experiment, which is currently being set-up, will provide a deeper understanding of how to build and operate a small-scale speed-meter interferometer and set the stage for further investigations of this topology. However, bridging the gap between the “bench-top“ scale experiment and the implementation in a large-scale GW observatory demands for a larger prototype in which techniques for the reliable operation of the speed-meter topology can be developed, including e.g. tests of optics and control systems.

To reduce thermal noise, future low-frequency detectors will most likely employ cryogenically cooled test masses. Hence, for a medium-scale prototype it is straight-forward to employ optics based on silicon as bulk material and to operate the interferometer at a laser wave-length of 1550nm.

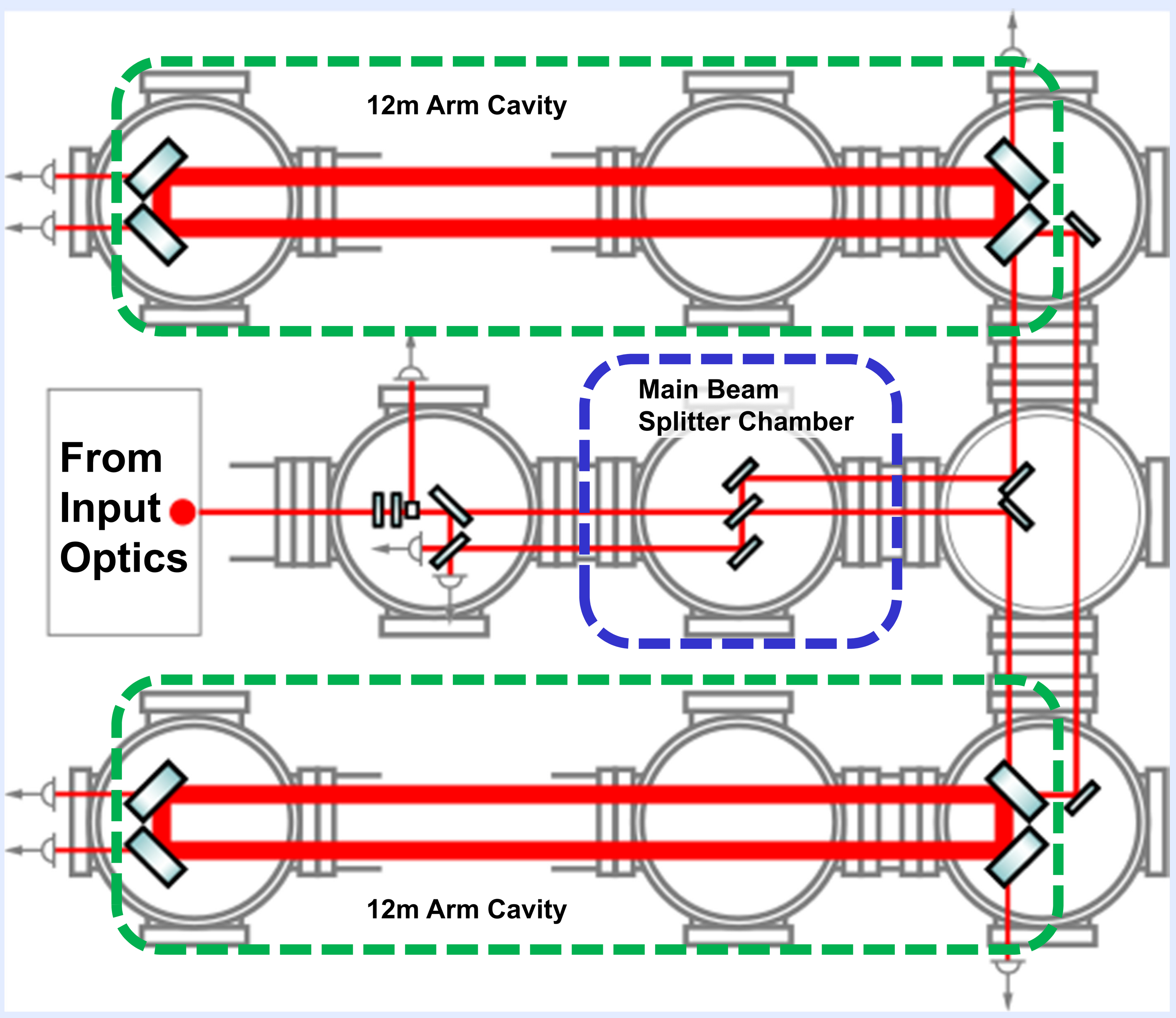

Figure 2: Optical layout of the Sagnac configuration with ring cavities in the vacuum system of the Glasgow 10m Prototype facility.

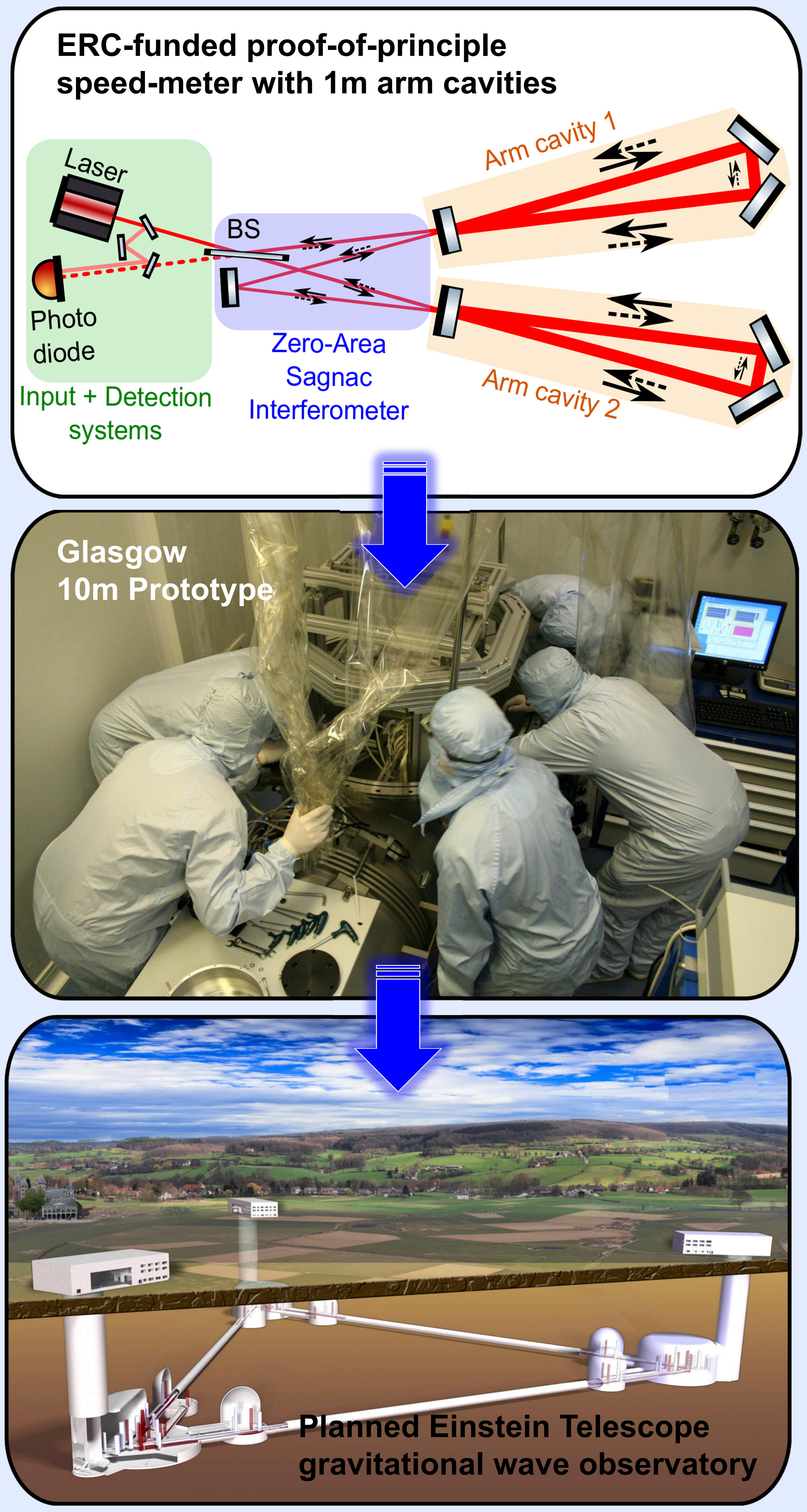

Figure 1: Building on the small-scale speed-meter experiment (top picture), a medium-scale prototype, built and operated in the Glasgow 10m lab (middle picture), will enable the development of techniques required for the reliable operation of a speed-meter in a large-scale GW observatory, e.g. the planned Einstein Telescope (bottom picture).

The 10m Sagnac prototype programme

We propose the first four years of a six-year development plan for the design, construction and operation of the world‘s first medium-scale Sagnac interferometer with silicon optics in the Glasgow 10m Prototype facility. This programme includes:

1. Development of a stable, low-noise 1550nm amplified laser source for use with silicon optics, including the down-selection of suitable seed lasers
2. Detailed investigation of arm cavity design options
3. Implementation and characterisation of a single arm cavity in the Glasgow 10m Prototype lab
4. Completion of the full Sagnac interferometer to demonstrate stable operation; characterisation of its noise behaviour