Don’t waste, recycle!

Stable recycling cavities for Virgo

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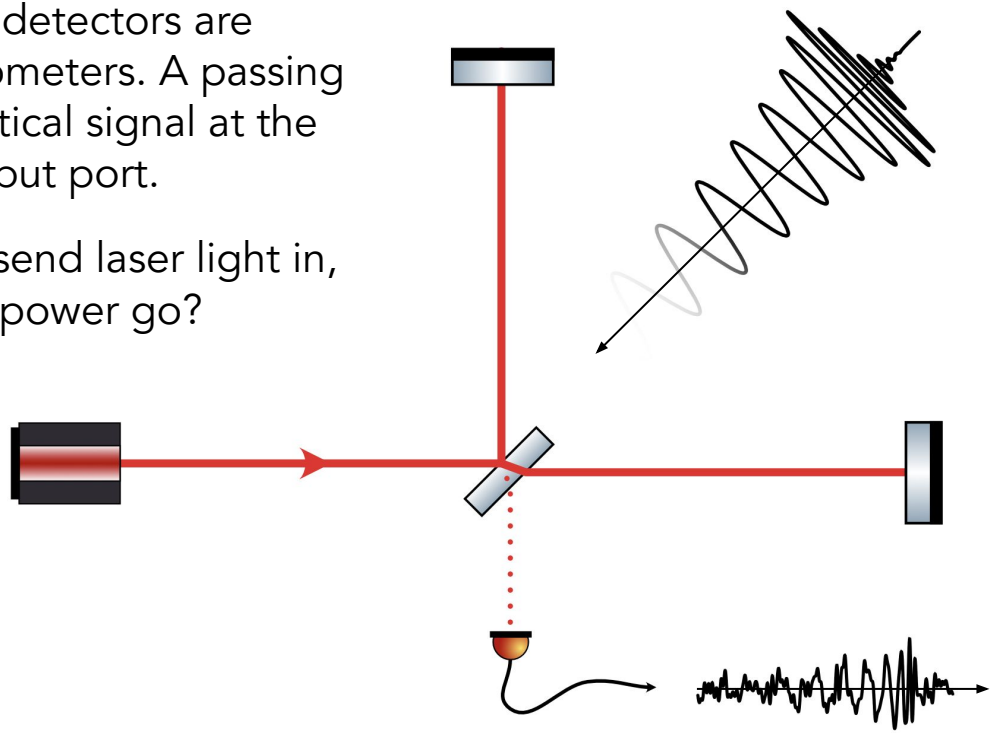
Where has all the power gone?

Gravitational wave detectors are Michelson interferometers. A passing GW leads to an optical signal at the otherwise dark output port.

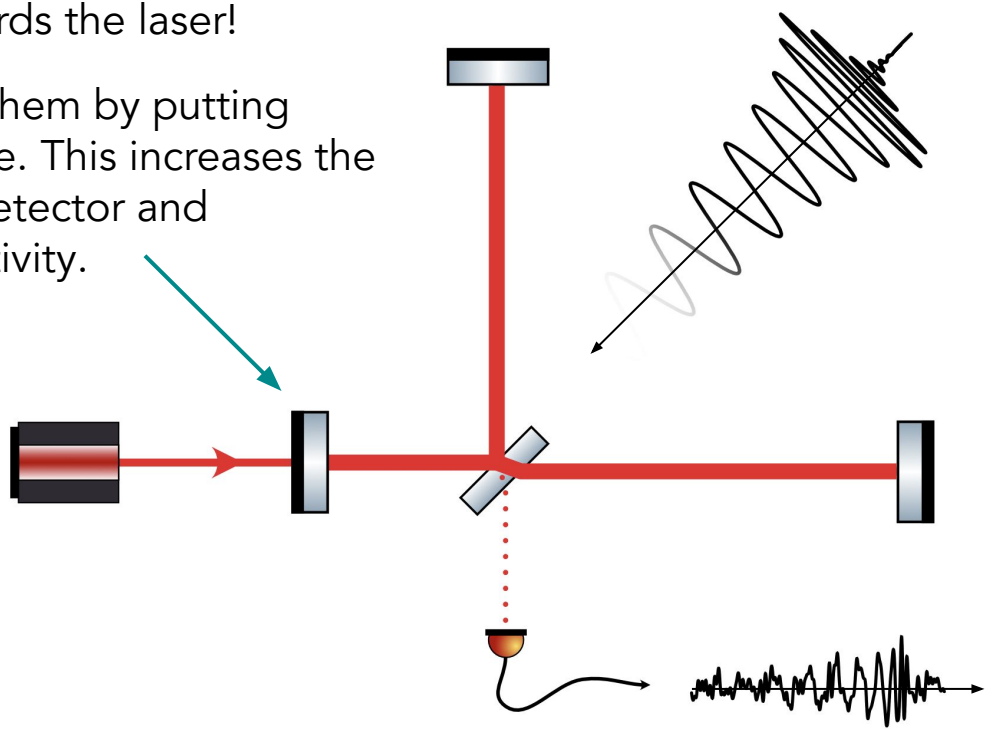
If we continuously send laser light in, where does all the power go?



Please re-use your laser's photons!

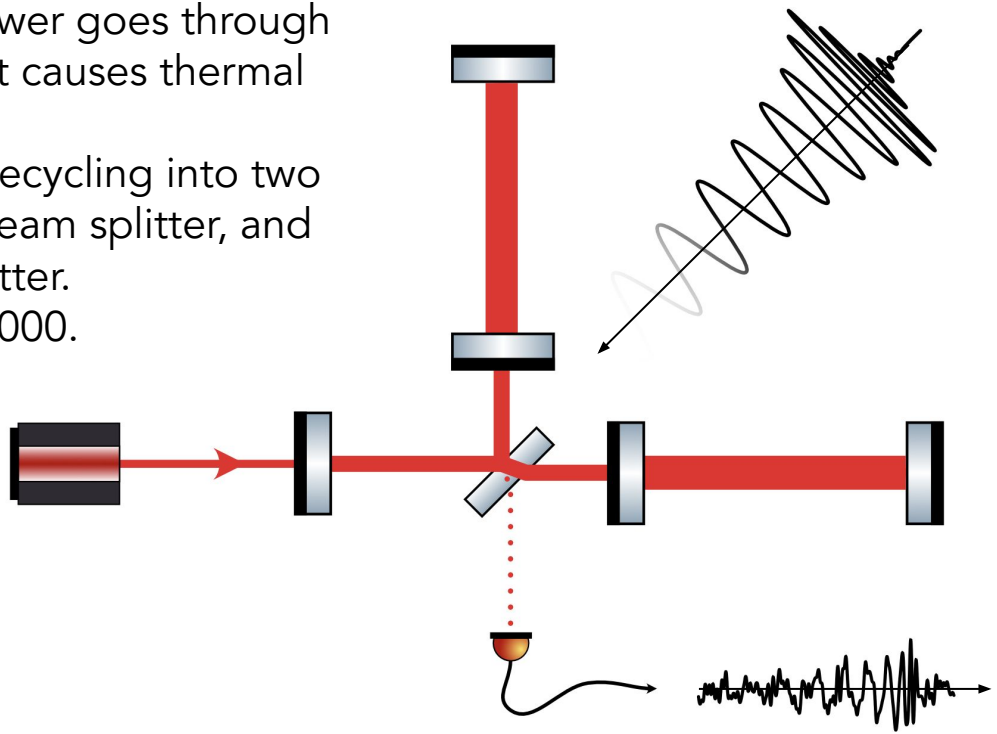
They go back towards the laser!

So we can recycle them by putting another mirror there. This increases the power inside the detector and therefore the sensitivity.



With great power comes great responsibility
(for thermal management)

Because all this power goes through the beam splitter, it causes thermal problems.
Better to split the recycling into two parts: before the beam splitter, and after the beam splitter.
In total, roughly x1000.



Building a trap for laser light

Light can be trapped between two mirrors. The light then bounced back and forth many times, determined by the reflectivity of the mirrors. This is an optical cavity.

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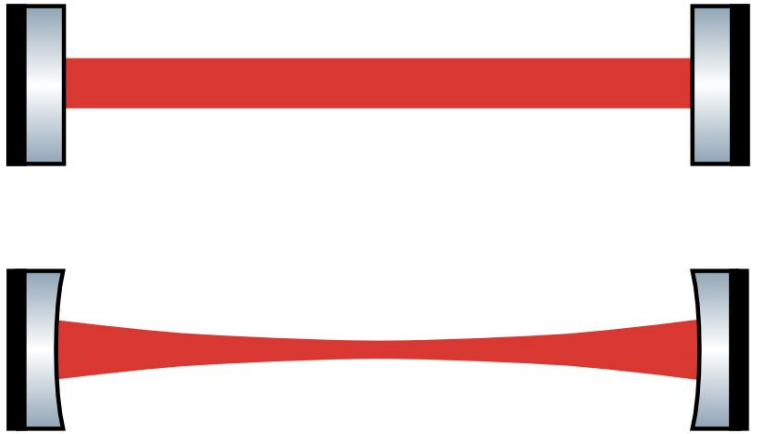

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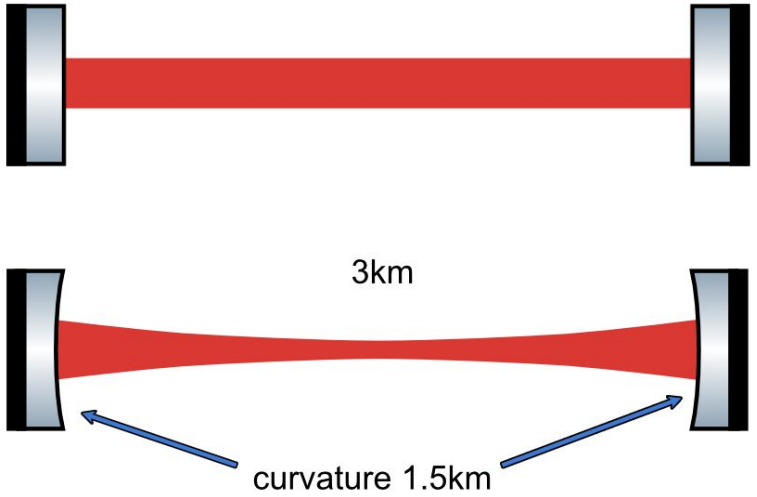
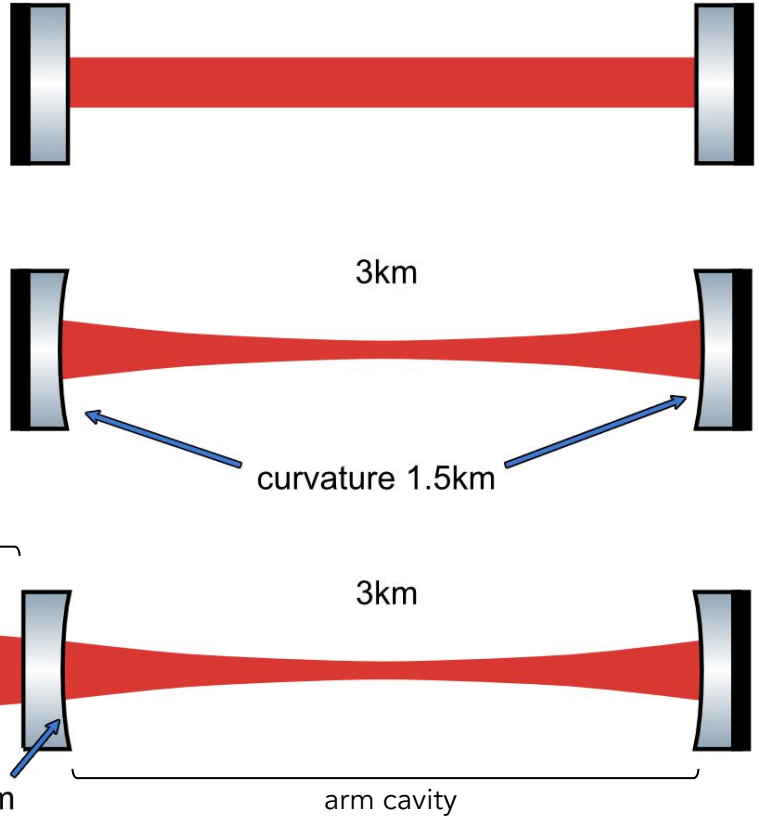
For the long arms of gravitational-wave detectors, the curvature is very long!



Building a trap for laser light

Adding the recycling mirror in front of the laser, we have two cavities that are coupled to each other; one quite short, the other very long.

For the short cavity, the curvature of the mirrors is much larger than the distance, so it almost looks like flat mirrors.

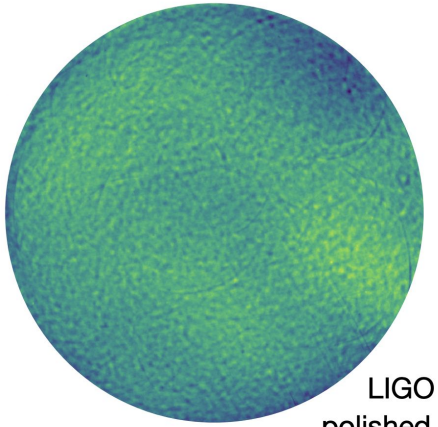


We're down-cycling the light

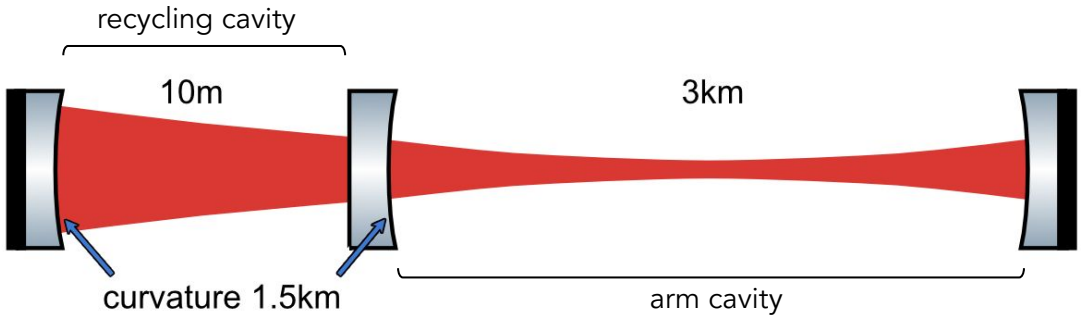
The almost flat recycling cavity means it is hard to keep the light confined.

Small misalignments of the mirrors, and even the tiny defects of the polished mirror lead to loss of light.

This is now limiting the sensitivity of Virgo (mostly because it impacts controls).



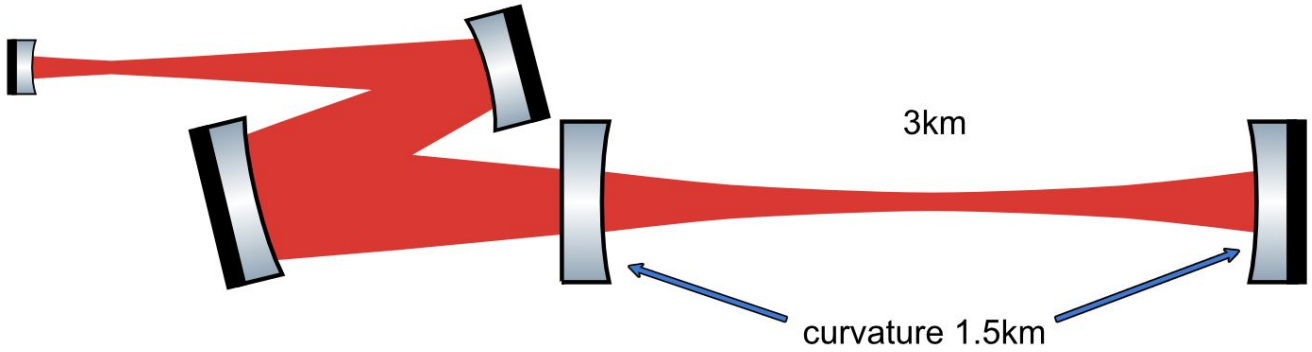
LIGO ETM08
polished surface



Let's up-cycle instead!

The recycling cavity needs to be built in a way such that it better confines the light field: it becomes a stable recycling cavity.

There are multiple ways to do this, but almost always this involves additional optics, suspensions and vacuum tanks. This is also the reason why stable recycling was not built into Virgo from the beginning.



Let’s up-cycle instead!

A challenging task in a legacy environment: not a lot of room for implementing the additional mirrors and corresponding vacuum towers.

Nikhef GW group involved in simulations, designs, reviews, and mechanics.

Disruptive work, but necessary to keep Virgo competitive for the next decade, until Einstein Telescope takes over.