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PHD THESIS

In the modern world we use electromagnetic waves as carriers of information everywhere from the optical fiber network, connecting the different parts of the planet, to the deep space network, relaying images taken by martian rovers back to earth. While the fiber network can sustain you with live streaming of high-definition videos and Gbit/s download speeds, the link connecting Mars and earth cannot. Yet we still send high quality camera and measurement equipment to the red planet that could leverage new discoveries quicker if only the connection was fast enough.
Just as a faint star in the night sky must be bright enough for you to see it, so bright must the data-carrying electromagnetic waves sent from Mars be for the receiver on earth to detect them. The transmitter on Mars has limited power to transmit, it can either allocate that power into fewer data bits with more energy, or more data bits with lesser energy. At risk of the receiver not being able to see "faint" bits, the former option is typically preferred, hence the limited speed of current deep-space communications. However, there is a solution.
Due to the wave-nature of electromagnetic radiation, the signal expands through space like the beam from a flashlight widens with distance. Interestingly, if the wavelength of the radiation is shorter, the spreading is reduced. This is the reason behind the emerging laser space-communication technology we see today. For deep space communications, lasers enable a narrower beam than traditional radio frequencies, which means more power striking the receiver, which in turn could allow more bits per second to be transmitted.
Even more bits per second could be transmitted if both the collecting area of the receiver was increased and the detector noise was decreased. These are the two aspects investigated in this thesis. It turns out that the short wavelength of laser light is a double-edged sword as although we get a narrower beam, we then also require more accurate pointing and high quality telescopes to efficiently focus the light into the sensitive low-noise detector. Here we consider different telescope designs and free-space to detector-coupling technologies for efficient detection. We also consider a specific type of detector based on a phase-sensitive optical amplifier that can amplify the light with half as much noise as commonly used amplifiers. The implementation of phase sensitive amplifiers do however require the received wave to be synchronized with the detector which poses significant practical challenges, many of them we solve within this thesis.

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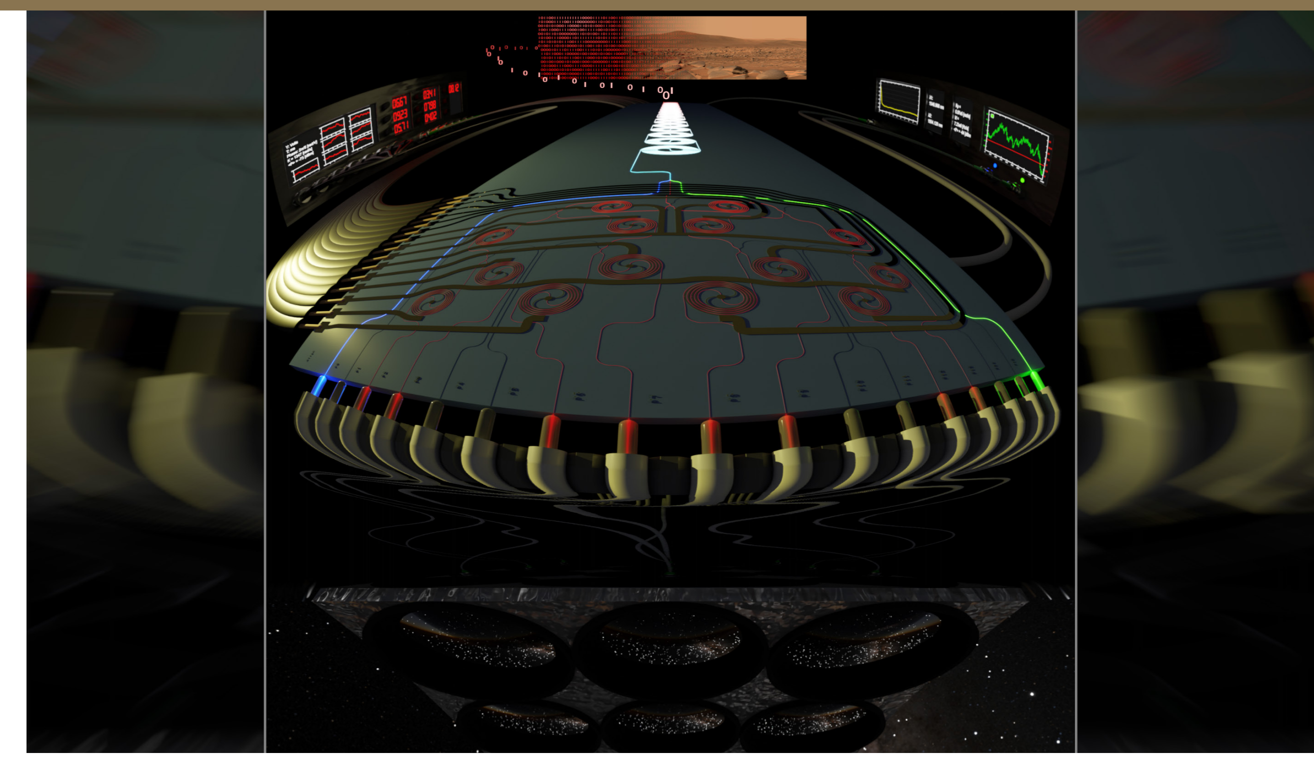
RASMUS LARSSON

High sensitivity receivers for free-space optical communication links

2024



High sensitivity receivers for free-space optical communication links

RASMUS LARSSON

DEPARTMENT OF MICHROTECHNOLOGY AND NANOSCIENCE MC2
CHALMERS UNIVERSITY OF TECHNOLOGY
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www.chalmers.se