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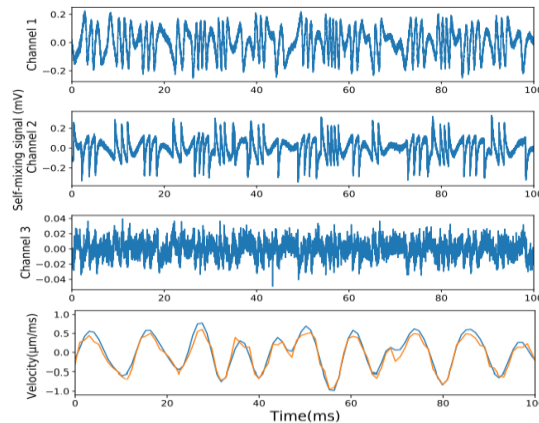
# High availability motion sensor with nonlinear interferometry and AI

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Self-mixing interferometry is a well-established technique in which a laser (often a semiconductor laser) is submitted to an optical feedback after reflection of the beam on a target. The operating point of the laser is altered depending on the phase of the reflected field. Among many applications, this method can be used to measure the displacement of a target along the propagation axis [1]. One can monitor these alterations of the operation point by a direct measurement of the voltage at the terminals of the laser diode. When the target moves in one direction or an other, the signal follows a sawtooth shape, for which each transition corresponds to a  $\lambda/2$  variation of the feedback phase. In general, reconstructing the displacement from an interferometric signal is made by identifying and counting peaks, or fitting a model on the signal. However, the actual amount of light fed back into the laser has a large impact on the shape of the signal and (in the case of non-cooperative targets), this amount of feedback is hard to control. This particularity makes the technique harder to use with non-cooperative targets, in which speckle phenomena can easily bring the system outside of the desired parameter range. Thus, many approaches have been taken to control this feedback level and/or to design ad-hoc signal processing techniques for the reconstruction of the displacement from the interferometric signal [2].



**Figure 1:** Three self-mixing signals (three plot on top) corresponding to the same displacement (bottom plot, blue) and the prediction made by the AI network (bottom plot, orange)

Recently we have shown [3] that a simple convolutional neural network (after proper training) can reconstruct the displacement of a target in a broad range of operating regimes. However, this can only work if the information is present in the interferometric signal: If (due to speckle) the feedback field goes to 0 or to a too large value, the self-mixing signal does not contain the information anymore. We address this measurement availability issue by proposing a hybrid sensor based on three independent self-mixing channels equipped with a neural network. After proper training, the network can infer the displacement from the interferometric signals (bottom panel). In this contribution, we discuss how this approach improves the measurement availability: We quantify the robustness of the system to detection noise on one, two or all three channels by comparing it to reconstructions on the individual channels (top three panels). We also demonstrate that the system is robust to complete channel loss thanks to the capacity of the neural network to extract information from the channels depending on their availability. Thus, we demonstrate that this hybrid approach based on a complex photonic system and artificial intelligence provides a high availability measurement system in the form of a compact, low energy and accurate sensor, whose applications are of course not limited to displacement sensing. More generally, we believe that bridging complex photonics and neural networks opens the way to a wide range of multi-channels and multi-modality sensing applications.

## **Bibliography:**

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