# What is the relationship between laser power and sensitivity?

**What is the relationship between laser power and sensitivity?**
In order to make measurements of the highest sensitivity, two things are required:

- High absolute count rate sensitivity
- High signal-to-noise

**How is high count rate achieved?**
Count rate sensitivity is achieved in a number of ways. From a hardware perspective, these include:

- Laser power
- Detector sensitivity
- Scattering volume

Absolute sensitivity is dependent on all of these factors so a high laser power is a factor in overall sensitivity; however, a high power laser is not enough to ensure high sensitivity on its own.

A comparison of laser power and sensitivity is therefore a false comparison because laser power is only one component of sensitivity. For example, a system with a 100mW laser and a photomultiplier tube will never be as sensitive as the Zetasizer Nano with a 4mW laser and an avalanche photodiode (APD).

**How is sensitivity tested?**
The best measure of absolute system sensitivity is to measure the scattering intensity from Toluene. Pure toluene is a stable sample with a very well characterized and predictable level of scattering. All Zetasizers are tested to ensure they have a required level of scattering from a sample of toluene.

**How do the Zetasizers achieve high sensitivity?**
Although the Zetasizer Nano ZS has a relatively low power laser (4mW), the sensitive detector (APD) and the large scattering volume afforded by NIBS make the system extremely sensitive for size. In fact, it is so sensitive that it can measure the baseline scattering from pure water. On the other hand, the Zetasizer µV and APS have higher power lasers (50mW) focused into small scattering volumes but have the same APD. Overall the absolute count rate sensitivity is very similar between the systems.

The zeta optics in the Nano ZS receive only a small fraction of the total laser power (approximately 10%) and the scattering volume is smaller so the absolute count rate sensitivity is much less than the size optics (>100x less sensitive).

To overcome this, the Zetasizer Nano ZSP has a more powerful laser (10mW). The optical configuration has also been modified to route a higher fraction of the laser power to the zeta optics. The overall increase in laser power to the zeta optics is approximately 12x resulting in a count rate improvement of approximately the same ratio.

**How is high signal-to-noise achieved?**
The other side of sensitivity is high signal-to-noise. This means that the collected scattered light is not combined with interference such as flare or unstable laser power. Sources of noise include:

- Lens flare
- Variable laser power
- Solvent scattering

**How do the Zetasizers achieve high signal-to-noise?**

The Zetasizers use very stable lasers. The He-Ne gas laser used by the Nano is particularly stable resulting in minimal noise. Additionally, the optical setups of the Zetasizers is very tightly designed, controlled and tested to make sure there is minimal optical noise from sources such as flare.

**How is signal-to-noise measured?**
Signal-to-noise is measured by the intercept in the correlation function. A high intercept implies excellent signal-to-noise. This can easily be seen by measuring a sample such as 60 nm latex. The high intercept indicates an excellent measurement with high signal-to noise.

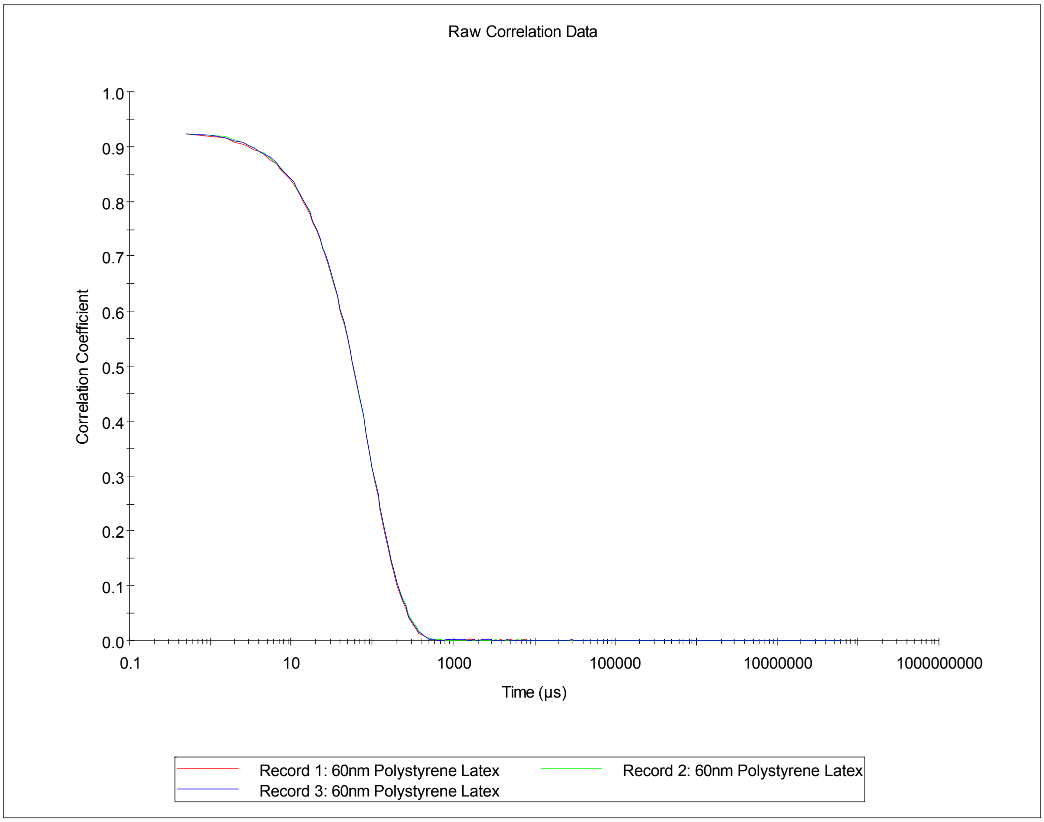


***Figure 1: 3 overlaid correlation functions from 60 nm latex with an intercept >0.9.***

A side by side comparison of correlation functions and intercept will demonstrate the performance of the Zetasizer.

**Where does solvent scattering come in?**
All molecules scatter light. Whereas the sample molecules and particles scatter light that contains signal, the dispersants and solvents scatter light which, for the purposes of our measurement, is noise. When measuring a sample, then, the final component of a good measurement is the amount of excess scattering (scattering of sample above scattering from solvent), and this is sample dependent.

**How does solvent scattering affect the measurement?**
Since the NIBS optics are already sensitive enough to measure solvent scattering it is very difficult to improve the sensitivity further since at low concentrations, the level of excess scattering is very low. For example, the solvent scattering from water is approximately 25 kcps. The scattering from a sample of 0.1 mg/ml Lysozyme is approximately 32 kcps meaning the excess scattering is only 7 kcps. The signal-to-noise is therefore lower resulting in low intercepts at the limit of sensitivity.

However, the Zetasizer Nano, μV and APS still have the capability to measure the size when the level of excess scattering is so low.

Therefore increasing the laser power does not increase the sensitivity because the NIBS optics are already extremely sensitive.

The Zeta optics in the ZS are over 100x less sensitive than the NIBS optics. They are unable to see solvent scattering and also see only limited sample scattering. By increasing the laser power in the ZSP, the level of sample scattering (excess scattering) has been increased over 10x but the system still does not see the solvent scattering from water. Overall, then, even though the sensitivity of the zeta optics in the ZSP have been improved by 10x, they are still approximately 10x less sensitive than NIBS.

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