Response to "Comment on 'High efficiency electron spin polarization analyzer based on exchange scattering at Fe/W(001)'" [Rev. Sci. Instrum. 80, 057103 (2009)]

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(Quotes from Ocaña's comment in italics)

In the abstract of his comment concerning the characterization of our spin detector, Ocaña[1] claimed that *"the results obtained with the same detector without oxygen coverage show a better performance in terms of both asymmetry and figure of merit."*

The fact that clean Fe(100) surfaces can be used for spin polarimetry is well known as we stated in the introduction of our paper. Ocaña claimed that these surfaces show a *quantitatively* better performance than surfaces prepared with oxygen. However, at the same time, he stated that only a *qualitative* comparison of the figure of merit of the detector should be made *"since the polarization of the incident beam has not been measured in situ."* If the second claim shall have any value, the first claim is meaningless in which Ocaña *did* clearly claim a quantitative improvement. This self-contradiction repeats itself in his conclusion. The statement *"The values obtained for both asymmetry and figure of merit are larger than those shown there* (in Ref. 2), *and hence demonstrate a better performance."* is invalidated by *"at this state of the experimental setup only qualitative and not quantitative comparisons should be made."*

Ocaña stated that *"an enhancement of the asymmetry is more efficient than the increase of the reflectivity."* The measured asymmetry cannot be enhanced if the spin polarization and the spin sensitivity are kept constant. The relevant measure is the spin sensitivity S (Sherman function) of the spin detector because the measured asymmetry is a function of the investigated system and not of the spin detector alone. This mistake is repeated several times: "*the main magnitudes that characterize a spin detector: the asymmetry and the figure of merit*" and in the summary: *"The values obtained for both asymmetry and figure of merit are larger than those shown there, and hence demonstrate a better performance."*

A higher asymmetry does *not* imply a better performance. In the caption of Fig. 1, Ocaña claimed that the data were taken for *the same experiments* as in our paper.[2] The measurements claimed by Ocaña and our published data were taken about a year apart with some important changes in the experimental setup. In this situation it is not valid to talk generally about the *"same experiments."* Only the data explicitly presented by Ocaña in his comment can be used to support his claims. Anything else alludes to suppositions and assumptions which are not proven.

To support his first claim, Ocaña showed in Fig. 1 data for three different measurements from at least two different samples [Fe/Cu(001) and Co/Cu(001) films] that emit spin-polarized secondary electrons and spin-polarized photoelectrons to be measured in the spin detector. The spin polarization of the emitted photoelectrons and of the secondary electrons can be generally expected to depend on the kinetic energy of these electrons as well as on the light polarization in case of the photoemission experiment and the primary beam energy in the measurements of the secondary electrons. Furthermore, there are strong differences between one-photon-photoemission and nonlinear two-photon-photoemission measurements, while Ocaña speakes only of "photoemission." None of this necessary information is given. It is also not stated whether these data for three different experiments were obtained with one and the same prepared Fe film in the spin detector or whether these data for three different types of experiments were obtained using three *different* Fe films in the spin detector.

Looking at the data presented in Fig. 1, the upper panel is supposed to show the reflectivity of the Fe film in the spin detector. This reflectivity must be magnetization dependent for the detector to work, but no magnetization dependent reflectivity is shown (as is explicitly done by us in Ref. 2). We guess that Ocaña showed the magnetization averaged reflectivity, which he did not state. If the experiments were done with one and the same Fe film in the detector, these curves should coincide within the experimental error. We can see that the three curves are distinctly not coinciding, with the curve for the 12 ML Fe/Cu(001) sample deviating clearly from the Co/Cu(001) data. Thus we have to assume that the measurements were done for three different Fe films in the spin detector, otherwise we would have to immediately assume that the reflectivity in the spin detector can depend on the investigated sample, which would imply a possible measurement mistake. In this interpretation, the upper panel thus would illustrate the degree of variations in the reflectivity for different Fe films prepared in the spin detector. This is our interpretation; no discussion concerning this fact is given by Ocaña. This implies that *three distinctly different experiments* [photoelectrons versus secondaries, Fe/Cu(001) versus Co/Cu(001) and three different Fe films in the spin detector] were done. Thus, the data presented by Ocaña do *not* allow one to exclude that the reflectivity changes shown are some kind of measurement artifact. This makes all other data in the figure ambiguous. (A methodologically correct investigation would need to show the presumed reflectivity variations for one constant reference system.)

Coming to the specific quantitative statement made by Ocaña, we proceed to estimate the figure of merit from his

data. At 12.8 eV for the 6 ML Co/Cu(001) film for the secondary electrons (star symbols in Fig. 1), the film reflectivity is about 0.05. Ocaña assumed an incident spin polarization of 0.35 at a measured asymmetry value of about 0.1. This gives a Sherman function of 0.286, and a figure of merit of 0.004, as he wrote in his comment. We note that this number has to be divided by 2 due to the fact that the measurements with reversed magnetization of the Fe film in the spin detector have to be taken one after another (the same procedure was applied in our publication[2]), leading to a final figure of merit of 0.002, which is not higher than our estimation.

Ocaña furthermore wrote that *"the derived figure of merit is in any case larger than that shown in* Ref. 2 *regardless of the values assumed for the spin polarization P*." This is clearly wrong. The "worst case scenario" for the figure of merit is $P=1.0$ (and not $P=0.0$). Assuming that $P=1.0$ with the upper values leads to an absolute lower boundary value of 0.0005 for the figure of merit, which is obviously lower than 0.004. Assuming unreasonably low values of P leads to meaningless large figures of merit.

At the end of his comment, Ocaña hinted at some possible mistakes in our experiments without giving any evidence in the form of verifiable data.

In summary, the data presented by Ocaña are ambiguous; a mistake in the calculation of the figure of merit was found and a number of arguments have been proven to be faulty. No quantitative evidence of a claimed better mode of operation of the spin detector was presented.

[1] R. Ocaña, Rev. Sci. Instrum. **80**, 057103 (2009).
[2] A. Winkelmann, D. Hartung, H. Engelhard, C.-T. Chiang, and J. Kirschner, Rev. Sci. Instrum. **79**, 083303 (2008).