MAGIS-100 Science & Simulations Meeting: Experimental Parameters Discussion

February 8, 2023

Agenda and slides posted on FNAL Indico: https://indico.fnal.gov/event/58279/

Objective: unify experimental parameters used and quoted by AION and MAGIS to support continuity for theory/sim work.

https://arxiv.org/pdf/1606.01860.pdf
https://arxiv.org/pdf/1711.02225.pdf
https://arxiv.org/abs/1911.11755
https://arxiv.org/abs/2109.10965
https://arxiv.org/abs/2203.14915
https://arxiv.org/abs/2211.01854
https://arxiv.org/abs/2104.02835v1 -- resonance parameters come from Fig 1 caption (specifically Fig 1-b)
https://arxiv.org/pdf/0806.2125.pdf: discussion on vibration-to-GGN coupling from zoom chat, section 4b1
https://arxiv.org/pdf/2211.05174.pdf
Lasers from chat: https://precilasers.com/en/page-29-24.html

Near Term goals & parameter choices:
3 technological development areas to reduce phase noise

1. LMT atom optics
2. Spin squeezing
3. Atom flux

For making plots: MAGIS Quantum Sci + Tech paper, there's an intermediate set of parameters used for DM search. Dual isotope mode solid curve was 100hk and 10^-3 radian phase resolution (dashed 1000hk, 10^-4 rad -- same for scalar plots). Q=1 (but this wouldn't change sensitivity plot as function of freq -- broadband vs narrowband)

We agree on long terms - but what are intermediate numbers? DM is core program for many labs (whereas GW is not), want to present a not-too-pessimistic scenario for DM searches. Is

this the best we can do: 1000hk and Q=1? Answer depends on DM mass range, could be that limitation is # pulses in sequence to preserve a useful contrast.

Different strategies/sequences for different mass/frequency ranges?

Maximize the early results to gain community support (focus on initial strategy to have largest impact on the field)

Long Term goals & parameter choices:
What is the asymptotic limit of these three technologies above? Reasonable vision for what can be done in the future.

Labs are interested in DM search, what can we optimize at the km scale to maximize DM sensitivity.

Strategy to run with different interrogation times to eliminate areas where DM frequency sensitivity is suppressed.

Multiplexed interferometers to increase cycle rate (doesn't improve phase noise, not increasing atom flux). Juggling multiple clouds in a region, sampling more often. Hard to control laser to do this with a fixed laser power - how to do LMT, avoid cross-talk? Could be done with velocity addressing. In addition, one can ask statistically about non-uniform time sampling.

What laser powers will be available in 20 years? Are we going to play a role in future laser development?

Underlying assumptions:
LMT projections: are we discussing the same interferometry sequence? MAGIS numbers are a resonant sequence with Q=5 (n=40k). Initial AION paper quoted nearly the same values as MAGIS tables.
The quoted 40k is a sensitivity scaling including both LMT and Q effects - make this more clear in future publications. "Disclaimer that the scale factor is 40k - still optimizing that between LMT and Q factors."

Quoted phase noise is for the whole apparatus, not at a single interferometer (clarify details)
Phase noise per atom source → MAGIS 10^-5 rad/root-Hz (assuming squeezed atom source)
Phase noise for full apparatus →
Same per-interferometer phase noise is quoted by AION paper

We should have these joint AION/MAGIS discussions more often. Even more broadly on scientific topics of interest.