**Specifications Sheet: Electrodes**

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**Functional specifications:**

The precession chamber consists of two UCN volumes sandwiched between two ground electrodes and a HV electrode in a vertical stack. The ground electrodes are separated by an insulator ring from the HV electrode. The back side of the ground electrodes should be able to support several components of the n2EDM experiment: Cs arrays, Hg polarizer, an interface with the UCN guides via a plug etc. The HV electrode will interface with a HV feedthrough to supply the HV. The connected power-supply is able to provide up to 250 kV, however, in the baseline design we assume voltages of up to 180 kV. The electrodes need to seal the UCN and Hg gas from the surrounding vacuum chamber volume by a seal on the insulator ring. The insulator ring also needs windows through which the Hg laser read-out light can pass. The Ramsey cells also require similar or better storage properties for the Hg gas and UCN as the previous nEDM experiment.

**Electrode dimensions:**

The electrodes have to fit an insulator ring with an internal diameter of 800 mm. The insulator also has to be centered by the electrode to ensure mechanical stability. The ground electrodes require access for interfaces for various items to be placed on top and below respectively: Cs magnetometer array, Hg magnetometer polarizer, and UCN plug with guides. The separation between the electrodes should be 12 cm, like in the nEDM experiment.

The thickness of the HV electrode directly determines the distance between the centers of the two chambers, $H^{'}$. This distance limits/restricts the maximum allowed magnetic field gradient. For example for an electrode thickness of 6 cm, $H^{'}$ is 18 cm, corresponding to an approximate gradient limit:

$$\left|\frac{dB\_{z}}{dz}\right|<0.6 pT/cm.$$

The electrodes should not bend more than 1 mm at their center compared to the groove which is supported by the insulator. If this was exceeded it could result in a different field in one chamber compared to the other. The requirement on the electric field asymmetry due to mercury quadratic frequency shift is: $d\_{n}<10^{-27}e⋅cm$, hence a field difference of less than 1% between the two chambers i.e. $\left|∆E/E\right|<10^{-2}$. If we required to be safe to $d\_{n}<10^{-28}e⋅cm$, this would require the electrode separation to be accurate to $120 μm$. However, as this is a two chamber setup, the difference in the two fields are compensated, therefore, it does not generate a false EDM.

**Electric field requirements:**

The electric field requires to be vertical within $ϵ<30 mrad$ (volume average) with respect to the z axis (axis of gravity). This assumes a false EDM due to $\vec{E}×\vec{v}$ effect, created by the net rotation of the UCN in the chamber:

$d\_{n}^{net}= 6.7×10^{-23} e⋅cm×\frac{ϵν\_{⊥}}{1 m/s}$,

where $ν\_{⊥}$ is the coherent motion < 1 cm/180s, which gives a false EDM of $d\_{n}^{net}<1×10^{-28}e⋅cm$. Due to this restriction, the electrodes have to be parallel, determined from the center of one electrode compared to the opposite (assuming one is perfectly perpendicular to the z axis) to $<30 mrad$.

The breakdown fields for vacuum $\left(<10^{-5} mbar\right)$ can be of the order 1 MV/cm, however, this requires an extremely careful conditioning process which would result in discharges on the electrode surfaces and probably damaging of the DLC coating of the electrodes. This process starts to occur at ~70 kV/cm.

A realistic estimate for the maximum allowed electric fields for the n2EDM electrode stack design, we can refer to the maximum achieved field in the nEDM apparatus. The highest achieved voltage in the nEDM experiment, without a discharge (performed without the presence of the fiber optic bundles), was 200 kV. From simulations we know that this resulted in a maximum electric field at the HV corona ring of about ~32 kV/cm. Hence, in our design for the n2EDM apparatus we aim to not exceed this value.

**O-ring sealing:**

The seal to the insulator and electrode can be realized with an o-ring similar to nEDM. It requires that the Hg gas does not escape the precession volume. The vacuum chambers target pressure is a water partial pressure of below $5×10^{-6}$ mbar plus partial pressures from other gas species (compare vacuum tank requirements – task 23), hence, we assume for the UCN volume to have the same target pressure to ensure consistency in the vacuum system.

The presence of the seal cannot affect the placement of the insulator; a misplacement could cause a variation in the parallelism of the precession chamber to the limitations stated previously.

The used material cannot have a high outgassing rate as this will interfere with $τ\_{2}$ time of Hg.

**Magnetic properties of the construction material:**

Construction material of the electrodes has to be non-magnetic, measured fields on the surface has to be $<20 pT$, at a distance of 5 cm after magnetization with 30 mT field (compare n2EDM TDR). Magnetizability of every pieces must be measured at PTB.

**Reversibility requirements for polarity switching:**

In order to limit the systematic effect due to the quadratic frequency shift of Hg in $d\_{n}^{+/-}<1×10^{-28}e⋅cm$ the absolute voltage applied to the central electrode needs to be the same in the positive and negative polarities with precision better than 0.1% i.e. $\left|ΔV/V\right|<10^{-3}$. Hence, a voltage stability similar to that of the high voltage power supply of $\leq \pm 1×10^{-4}$ in 8h is required.

**UCN and Hg requirements:**

The electrodes are to be made out of aluminum, then coated with DLC. The coating needs to be able to store UCN for better then 300 s. In order to achieve this the precession chambers must have the following parameters: $V\_{F}=220 neV, p\_{diff}=2\%, η=3∙ 10^{-4}.$

The depolarization of the neutrons due to wall collisions in the chamber is also an important parameter which effects the visibility of the Ramsey fringes. The depolarization rate is given by:

$\frac{1}{T\_{wall}}= νβ$,

where $ν≈50/s$ is the wall collision rate and β is the depolarization probability at a wall collision which is dependent on the surface. Assuming other depolarization mechanisms are negligible then the previous nEDM experiment achieved $T\_{wall}≈4000 s$, for which we expect the same in n2EDM.

Experience in the nEDM experiment told us that the depolarization of the Hg in the precession chamber was dominated by wall collisions. Previous the depolarization time, τ, varied between 130 and 60 seconds. Its planned that we will use the same coating for the insulator and electrodes (DPS and DLC respectively) and the mean free path will be very similar (18.5 cm instead of 16.0 cm for the previous experiment), we can assume we achieve similar τ.