ESRF Double Crystal Monochromator - Lookup Tables

Dehaeze Thomas

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1 Introduction

Several Lookup Tables (LUT) are used for the DCM in order to compensate for **repeatable** errors.

- Section 2: the stepper motors are calibrated using interferometers.
- Section 3: the Attocube periodic non-linearities are calibrated using piezoelectric actuators.

2 Stepper Motors Calibration

2.1 Schematic

2.2 Simulation

In this section, we suppose that we are in the frame of one fast jack (all transformations are already done), and we wish to create a LUT for one fast jack.

Let's say with make a Bragg angle scan between 10deg and 60deg during 100s.

Matlab
```
Fs = 10e3; % Sample Frequency [Hz]
t = 0:1/Fs:10; % Time vector [s]
theta = linspace(10, 40, length(t)); % Bragg Angle [deg]
```

The IcePAP steps are following the theoretical formula:

$$d_z = \frac{d_{\text{off}}}{2\cos\theta} \tag{2.1}$$

with θ the bragg angle and $d_{\text{off}} = 10\,mm$.

The motion to follow is then:

Matlab
```
perfect_motion = 10e-3./(2*cos(theta*pi/180)); % Perfect motion [m]
```

And the IcePAP is generated those steps:

Matlab
```
icepap_steps = perfect_motion; % IcePAP steps measured by Speedgoat [m]
```

Then, we are measuring the motion of the Fast Jack using the Interferometer. The motion error is larger than in reality to be angle to see it more easily.

Matlab
```
motion_error = 100e-6*sin(2*pi*perfect_motion/1e-3); % Error motion [m]

measured_motion = perfect_motion + motion_error; % Measured motion of the Fast Jack [m]
```

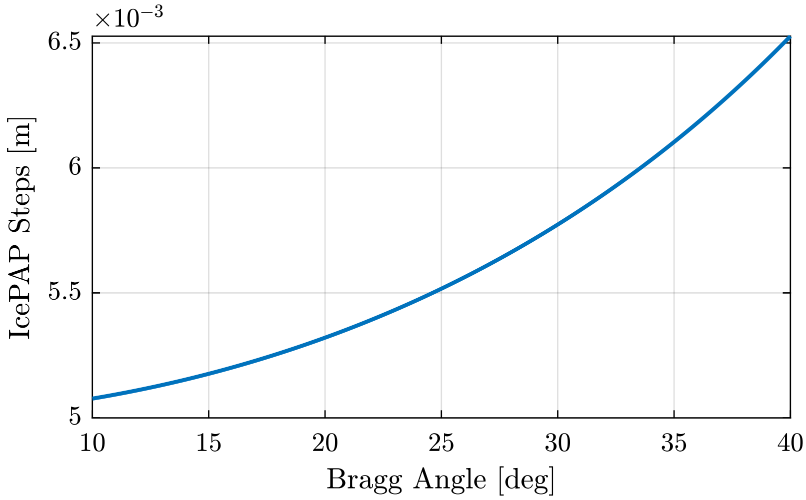

Figure 2.1: IcePAP Steps as a function of the Bragg Angle

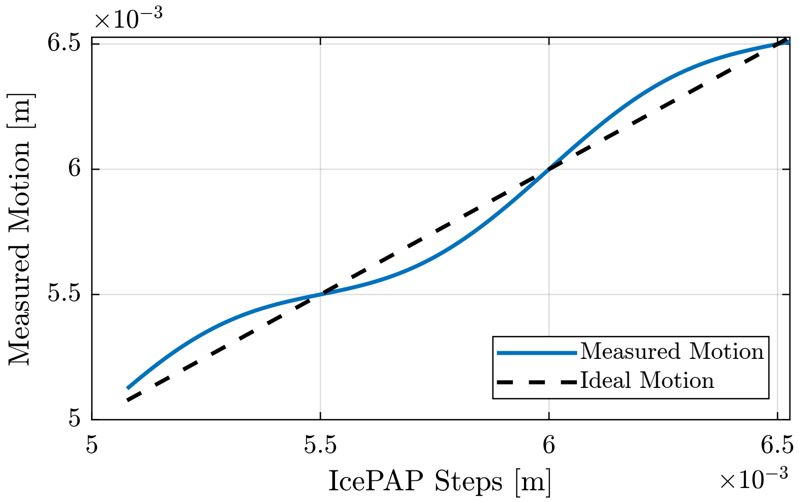

Figure 2.2: Measured motion as a function of the IcePAP Steps

Let's now compute the lookup table. For each micrometer of the IcePAP step, another step is associated that correspond to a position closer to the wanted position.

```matlab
%% Get range for the LUT
% We correct only in the range of tested/measured motion
lut_range = round(1e6*min(icepap_steps)):round(1e6*max(icepap_steps)); % IcePAP steps [um]

%% Initialize the LUT
lut = zeros(size(lut_range));

%% For each um in this range
for i = 1:length(lut_range)
    % Get points indices where the measured motion is closed to the wanted one
    close_points = measured_motion > 1e-6*lut_range(i) - 500e-9 & measured_motion < 1e-6*lut_range(i) + 500e-9;
    % Get the corresponding closest IcePAP step
    lut(i) = round(1e6*mean(icepap_steps(close_points))); % [um]
end
```

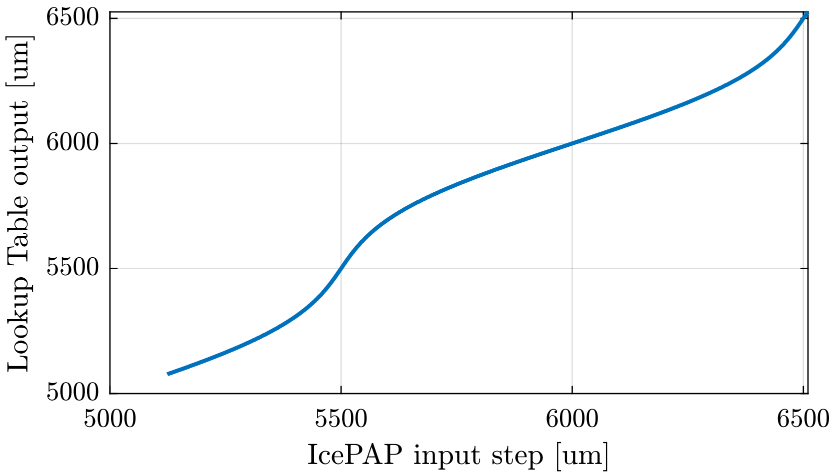

Figure 2.3: Generated Lookup Table

The current LUT implementation is the following:

```matlab
motion_error_lut = zeros(size(lut_range));
for i = 1:length(lut_range)
    % Get points indices where the icepap step is close to the wanted one
    close_points = icepap_steps > 1e-6*lut_range(i) - 500e-9 & icepap_steps < 1e-6*lut_range(i) + 500e-9;
    % Get the corresponding motion error
    motion_error_lut(i) = lut_range(i) + (lut_range(i) - round(1e6*mean(measured_motion(close_points)))); % [um]
end
```

Let's compare the two Lookup Table in Figure 2.4.

If we plot the "corrected steps" for all steps for both methods, we clearly see the difference (Figure 2.5).

Let's now implement both LUT to see which implementation is correct.

```matlab
motion_new = zeros(size(icepap_steps_output_new));
motion_old = zeros(size(icepap_steps_output_old));
```

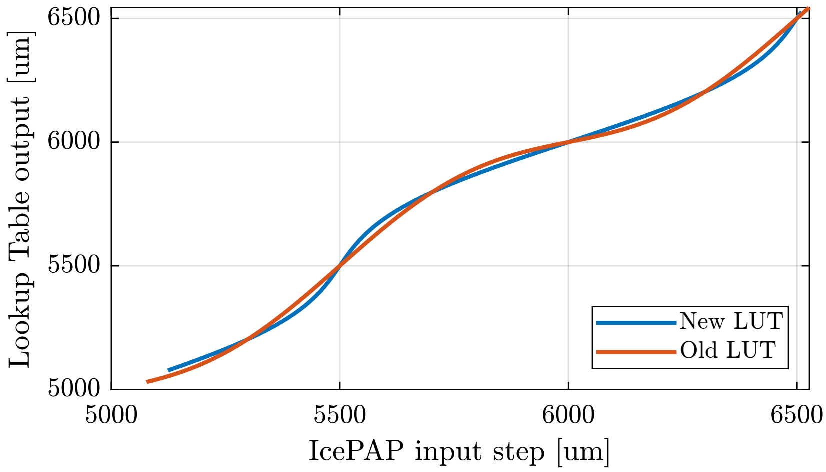

Figure 2.4: Comparison of the two lookup tables

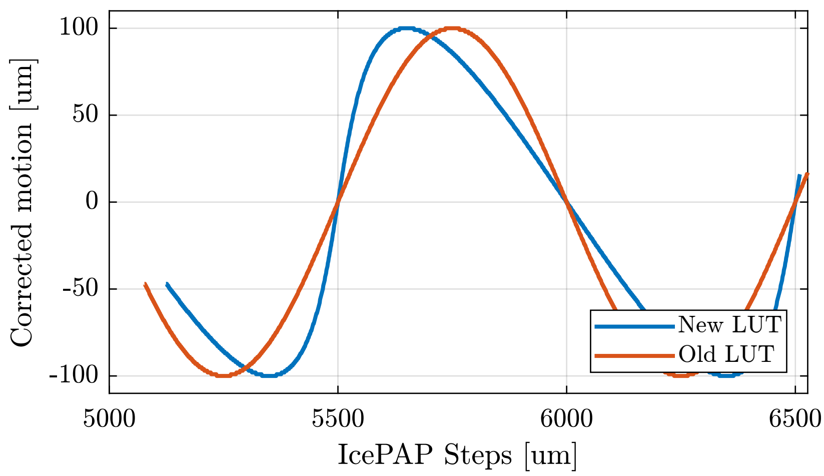

Figure 2.5: LUT correction and motion error as a function of the IcePAP steps

```matlab
for i = 1:length(icepap_steps_output_new)
    [~, i_step] = min(abs(icepap_steps_output_new(i) - 1e6*icepap_steps));
    motion_new(i) = measured_motion(i_step);

    [~, i_step] = min(abs(icepap_steps_output_old(i) - 1e6*icepap_steps));
    motion_old(i) = measured_motion(i_step);
end
```

The output motion with both LUT are shown in Figure 2.6. It is confirmed that the new LUT is the correct one. Also, it is interesting to note that the old LUT gives an output motion that is above the ideal one, as was seen during the experiments.

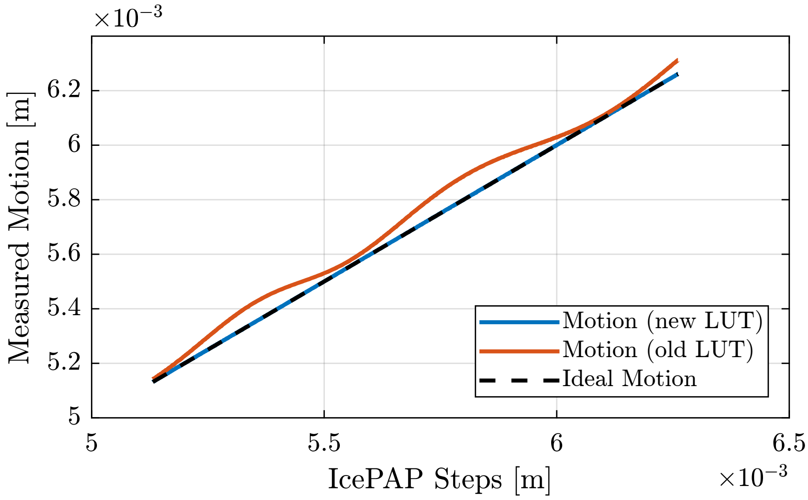

Figure 2.6: Comparison of the obtained motion with new and old LUT

3 Attocube Calibration