Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary information

Soft-chemistry-grown Pt tripods as highly-crystaline nanometric frequency multiplexing devices.

Bruno Camargo, Benjamin Lassagne, Raul Arenal, Christophe Gatel, Thomas Blon, Guillaume Viau, Lise-Marie Lacroix, Walter Escoffier.

Size statistics:

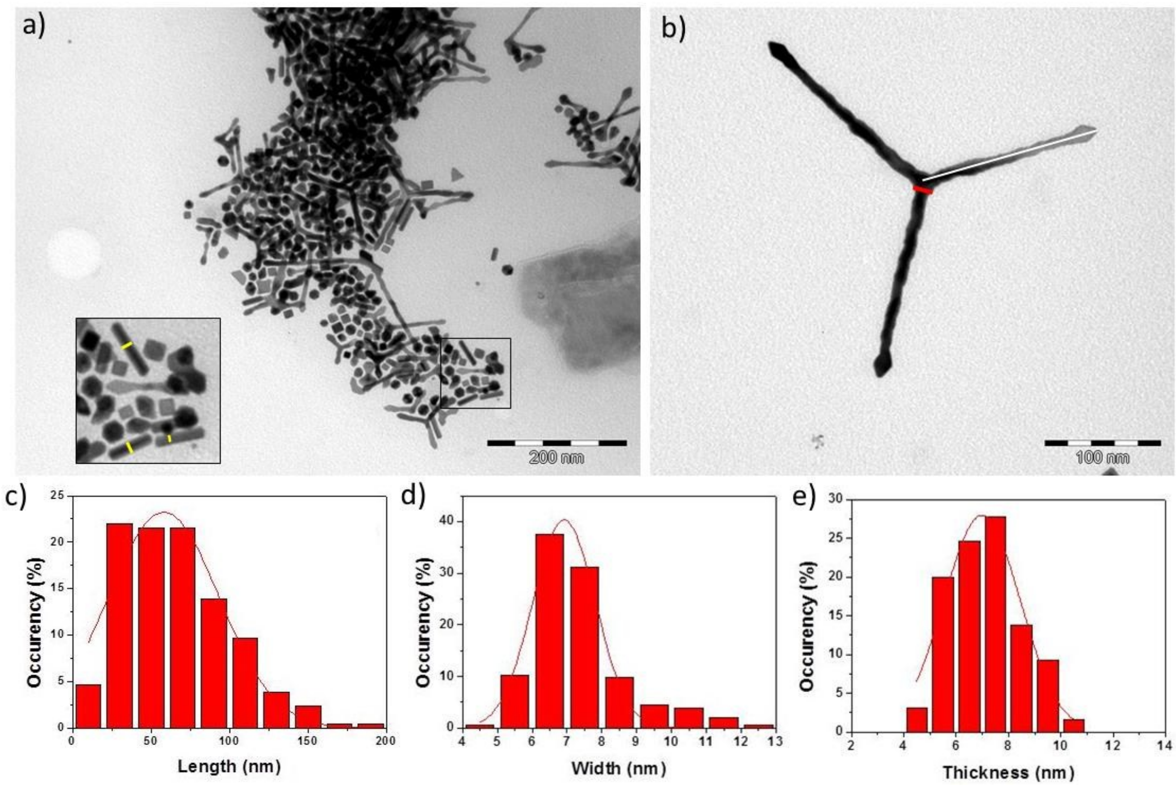

Figure S1 – a-b) Transmission electron microscopy (TEM) images of thin Pt nanostars and the corresponding c-e) size distribution of the tripods arms. The arm's length is measured from the star center to the arm's extremity (white line in b), the width is measured at the junction between the core and the arm (red line in b) while the thickness is measured on branches observed on the side (yellow line in a inset).

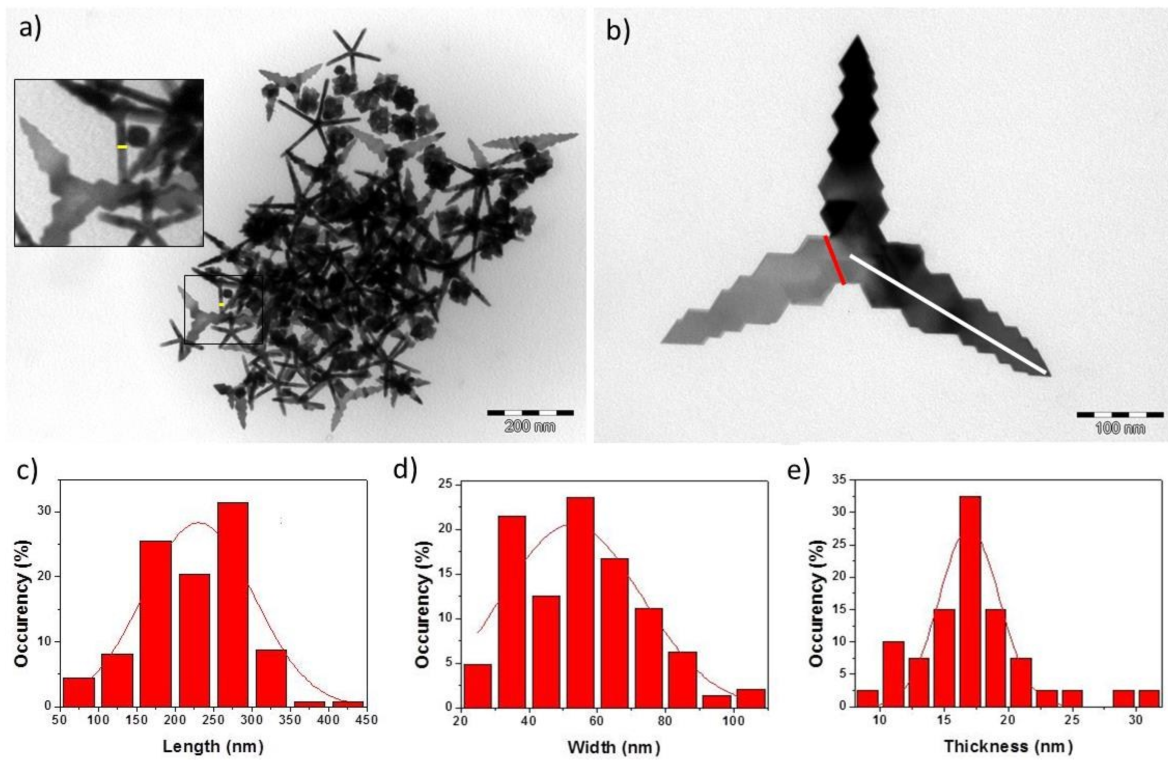

Figure S2 – a-b) Transmission electron microscopy (TEM) images of thick Pt nanostars and the corresponding c-e) size distribution of the tripods arms. The arm's length is measured from the star center to the arm's extremity (white line in b), the width is measured at the junction between the core and the arm (red line in b) while the thickness is measured on branches observed on the side (yellow line in a inset).

SEM Imaging:

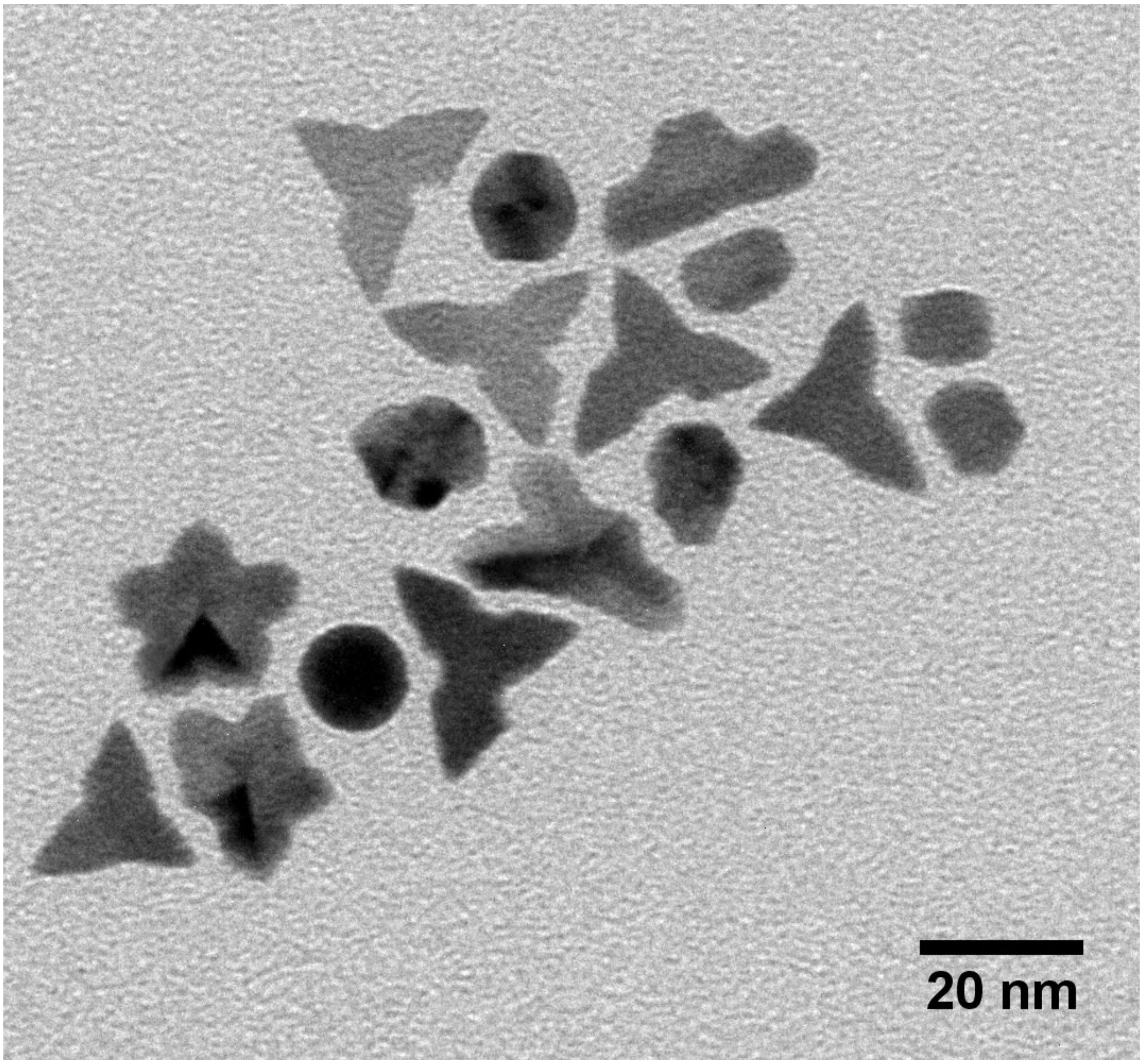

Figure S3. TEM image of the thin nanostars obtained after 6h of reduction under H_2 at 150°C. Decahedra and triangular seeds with small arms are observed.

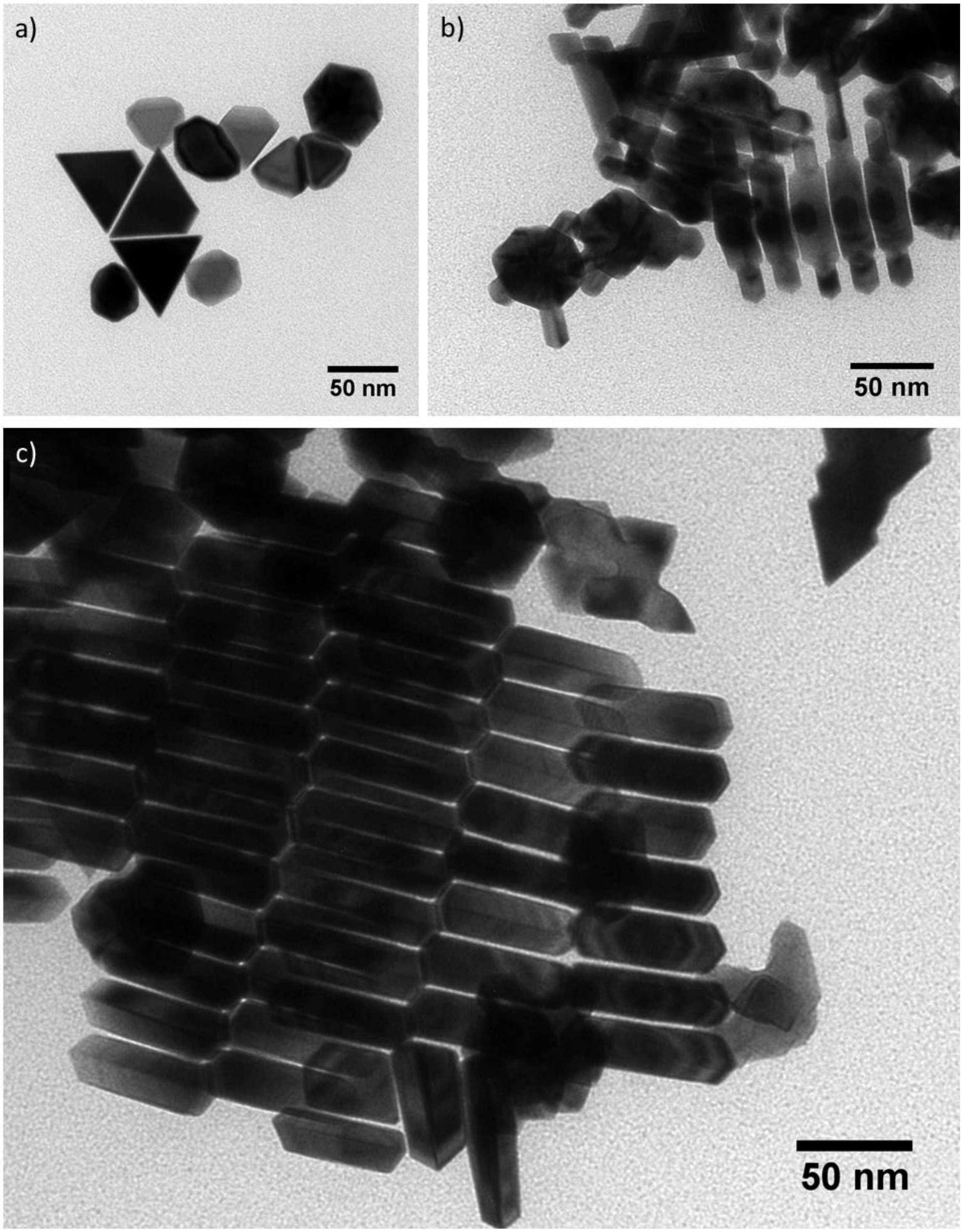

Figure S4. a-c) TEM images of the thick nanostars obtained after decomposing the intermediate Pt-oleylamine precursor under H_2 at 150°C for 24h. Large triangular seeds of ~50 nm are observed. c) locally the seeds could be found in a vertical array, evidencing the flatness of the object and the systematic presence of a twin plane within the triangular thickness.

AFM measurements:

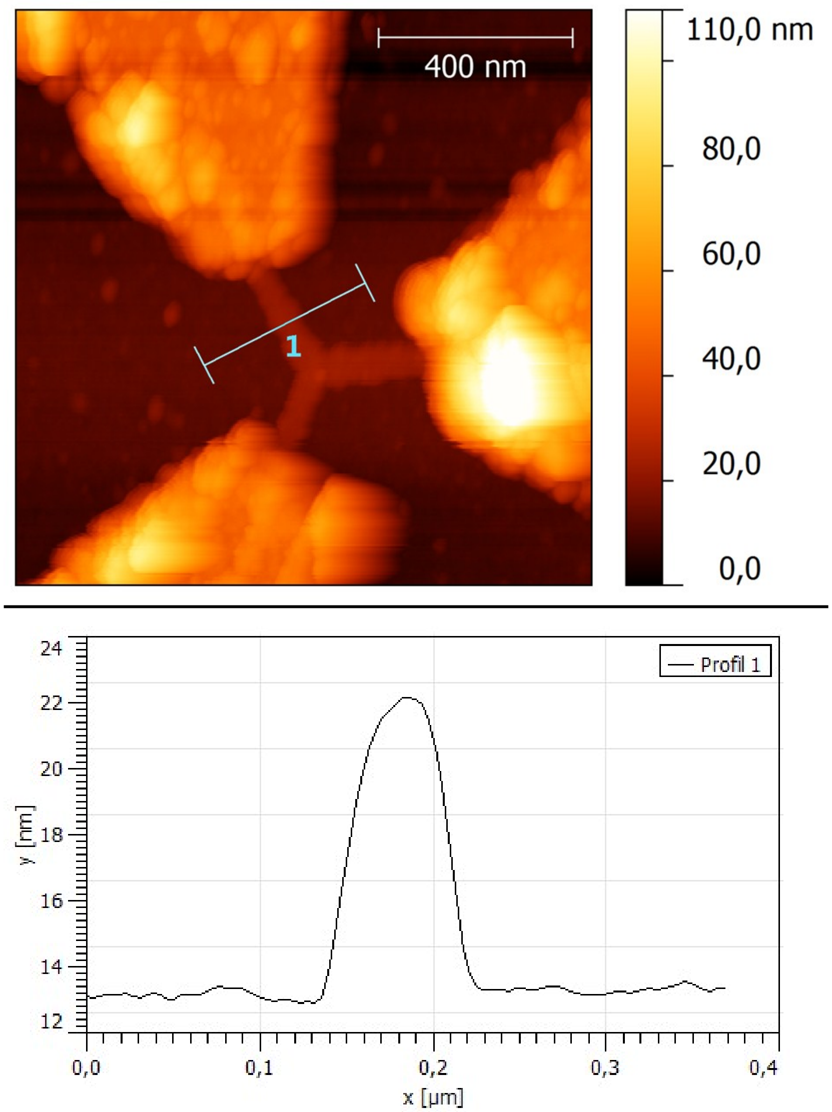

Figure S5 – Top panel: AFM image of a thick nanostar studied. Bottom Panel: Profile along the line labelled 1 in the top panel.

Contact and branch resistance:

Consider the star shown in fig. 3. Each branch possess a resistance R_k^B, whereas the contact between the branch and the electrodes hold its own intrinsic resistance R_k^C. When measuring the voltage between any two branches V_{jk} as shown in fig. 3 (see the main text), the contact resistance of every branch through which current flows will contribute to the measured value of V_{jk}.

Hence, when measuring the resistance of any branch i in the three-probe configuration, the current and voltages involved are:

$R_k = V_{jk}/I_{ik} = R_k^B + R_k^C$

Where the coefficients are interchangeable.

There is no linear combination of branches/contact resistances that allow us to separate branch from contact resistance. This happens because the contact resistance is always followed by the branch resistance. For completeness, three probe measurements can yield the following values:

$R_i = V_{ij}/I_{ik} = V_{ik}/I_{ij} = R_i^C+R_i^B$

$R_j = V_{ij}/I_{jk} = V_{jk}/I_{ij} = R_j^C+R_j^B$

$R_k = V_{ik}/I_{jk} = V_{jk}/I_{ik} = R_k^C+R_k^B$

Meanwhile, two-probe measurements yield the following

$R_{ij} = V_{ij}/I_{ij} = R_i^C+R_i^B + R_j^C+R_j^B$

$R_{jk} = V_{jk}/I_{jk} = R_k^C+R_k^B + R_j^C+R_j^B$

$R_{ki} = V_{ki}/I_{ki} = R_i^C+R_i^B + R_k^C+R_k^B$

Any linear combination of the expressions above does not allow to separate the branch and contact resistance with same indexes, no matter which set of measurements is chosen.

Non-linear regime in the push-pull configuration

We can approach our nanostar as three resistors assembled in a star configuration, as shown in fig. S6. In the push-pull geometry (schematized in the inset of fig. 5a of the main text), no electrical current is allowed to flow through one of the branches of the star. In this case, the potential at the center of the star (and, therefore, at branch k), can be calculated from Kirchoff law as

$V_k = V_{in}(R_j - R_i)/(R_j + R_i)$.

R_i and R_j refer to the resistance of branch i and j. Due the non-ohmic behavior of R_i and R_j (see fig. 5 of the main text), we can expand them up to the second order in V_{in} as $R_i = R_{0_i} + \beta_i V_{in}^2$. Substituting this form of R_i in the expression above yields

$$V_k = \frac{V_{in}\delta_0 + V_{in}^3\delta_\beta}{\Delta_0 + V_{in}^2\Delta_\beta},$$

With $\delta_0 = R_{0j} - R_{0i}$, $\delta_\beta = \beta_j - \beta_i$, $\Delta_0 = R_{0j} + R_{0i}$ $\Delta_\beta = \beta_j + \beta_i$. The lower indexes i, j refer to the branches i and j, respectively. This is the expression discussed in the text. Samples with small values of δ_0 (i.e. with branches possessing similar ohmic components or resistance), V_k presents stronger non-linearity, resulting in more prominent frequency multiplication.

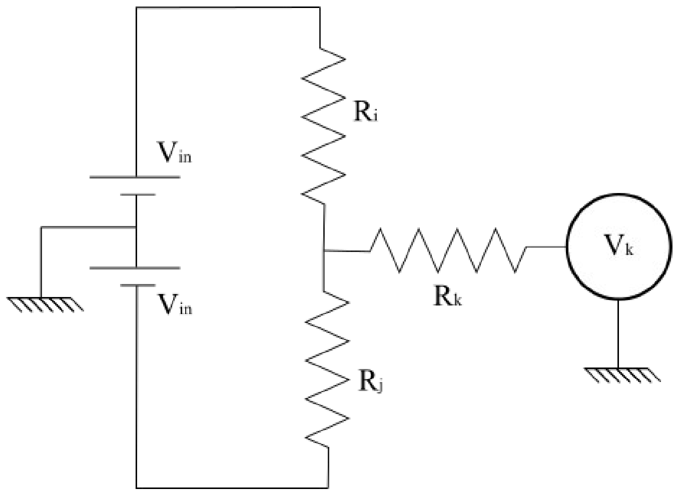

Figure S6 – Equivalent circuit for the star measured in the push-pull configuration.

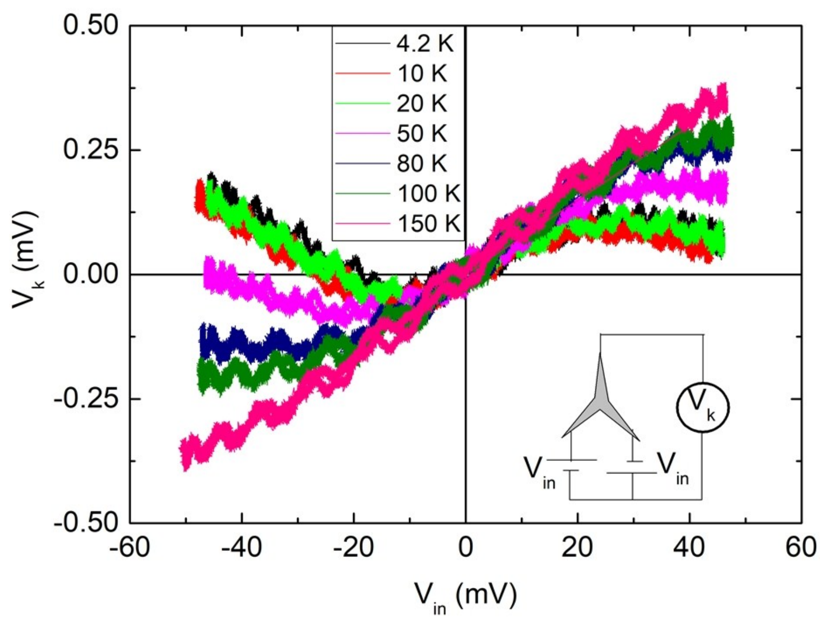

Figure S7 – Raw $V_k(V_{in})$ curves measure in the push pull configuration prior to smoothing. The quick oscillating features seen in the curves are caused by interference between both V_{in} sources in the push-pull configuration and is not of interest here.