



Femto-Electrospray Ionization: Ion Transmission Profile and Signal-to-Noise Enhancement

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Highlights:

- Ion transmission efficiency of femtoESI and nanoESI was investigated for three types of solutions.
- FemtoESI enhances signal-to-noise ratio for alkyl ammonium analyte in aqueous sample solution.
- Different characteristics within femtoESI suggest the presence of multiple spray modes.

Introduction:

- The dynamics of ionization current reveals the different electrospray modes, and their transitions.
- Signal-to-noise ratio is as important as intensity for good MS measurements.
- Ion transmission affects detection sensitivity and is influenced by ionization modes.

Methods:

- Direct infusion in femtoESI and nanoESI modes using single sample solution and (2.5-3.5 μm OD) emitter tips.
- Ionization current characterization using Keithley electrometer with 10 fA resolution in a low-noise faraday cage.
- Ion transmission efficiency is measured as the ratio between the total ion current (MS detector) to the spray current (source). Assuming all ions singly charged, 100% transmission will produce **6,520 ions per second**, for each 1 femtoampere (fA) of ionization current.

Femto and nano electrospray

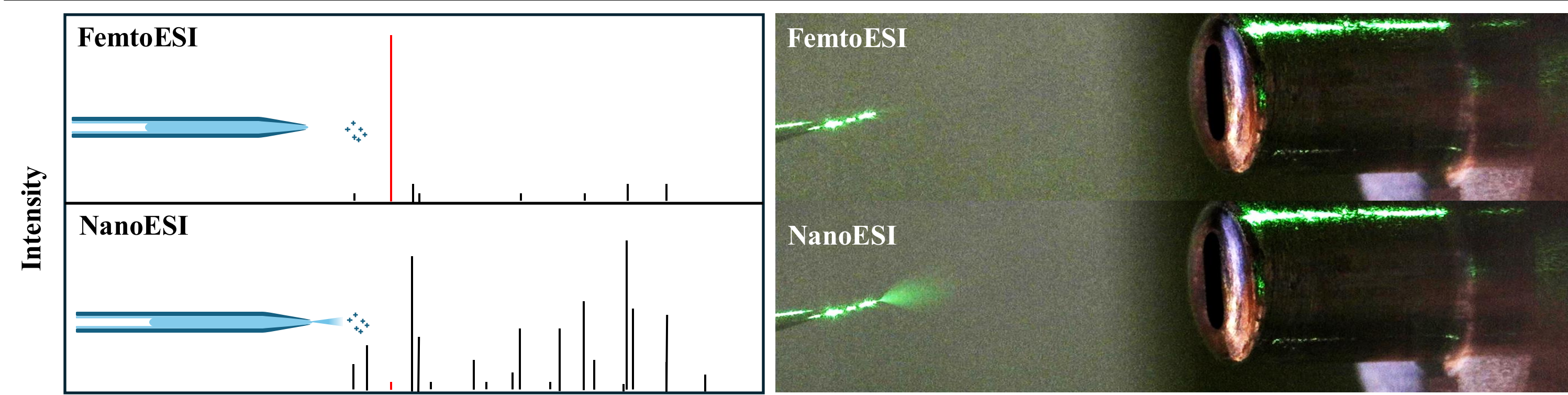


Figure 1. Left: femtoESI enhances signal (red) to noise (other peaks) ratio. Right: femtoESI with invisible plume suggests either smaller size (<400 nm) or much lower droplet density.

Protein in aqueous ammonium acetate solution: Lowest ion transmission

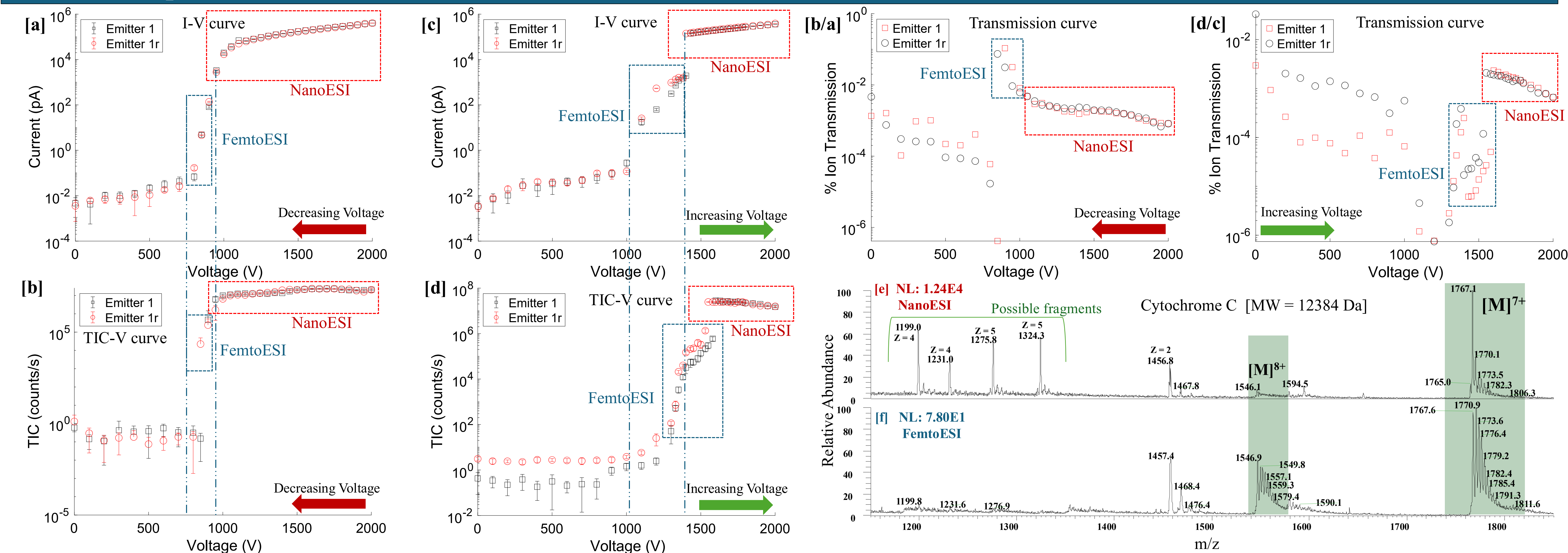


Figure (a). I-V and **Figure (b).** TIC-V curves collected for 10 μM Cytochrome C in 200 mM Ammonium Acetate solution by gradually reducing (←) the voltage from 2 kV to 0V, while **Figure (c).** I-V and **Figure (d).** TIC-V curves by gradually increasing (→) the voltage from 0 V to 2 kV. **Figure (b/a)** and **Figure (d/c).** Percent transmission for femtoESI (10⁻⁴%) compared to nanoESI (<10⁻²%) which is lowest probably due to highest conductivity. **Figure (e).** and **Figure (f).** Mass spectrum shows higher fragmentation in femtoESI (2 kV).

Alkyl ammonium in aqueous solution: Enhanced transmission & signal-to-noise ratio

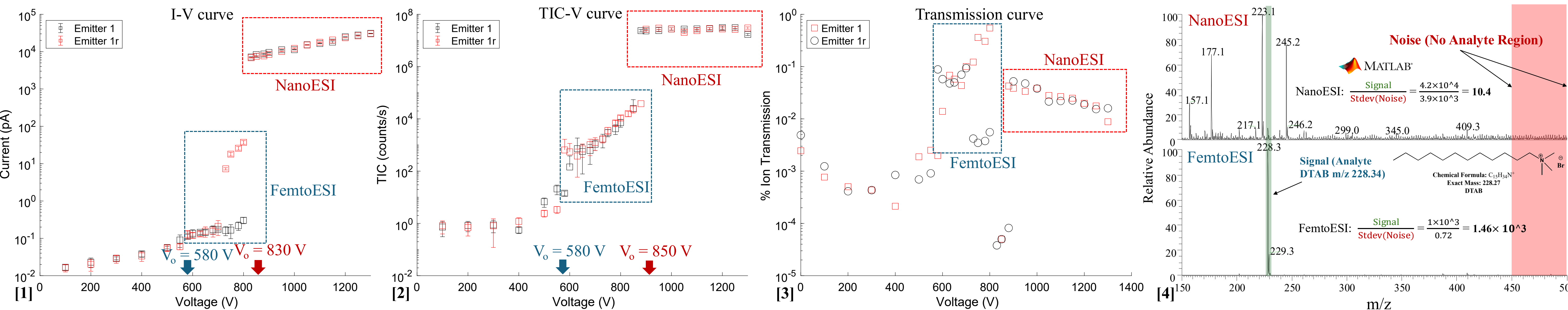


Figure 1. I-V and **Figure 2.** TIC-V curve for Aqueous 1 μM N-(n-dodecyl)-N, N, N-trimethylammonium bromide solution (DTAB) was repeated intra-day using the same emitter shown as **1** (Black) and **1r** (Red). The normalized level and spray current for the femtoESI [1-10⁴ cps, 0.1-30 pA] was observed compared to nanoESI [10⁷ cps, 10⁴-10⁵ pA]. **Figure 3.** Percent transmission calculated as ratio of ion current at the MS detector and spray current (pA) with highest transmission of ~0.5%. **Figure 4.** Standard deviation of data in **no analyte region** is treated as noise and analyte's intensity is directly isolated using same MATLAB script. The ratio of femto-to-nano signal-to-noise ratio's is ~139 times enhancement.

BiPy in toluene solution: Low and high femtoESI sub-modes

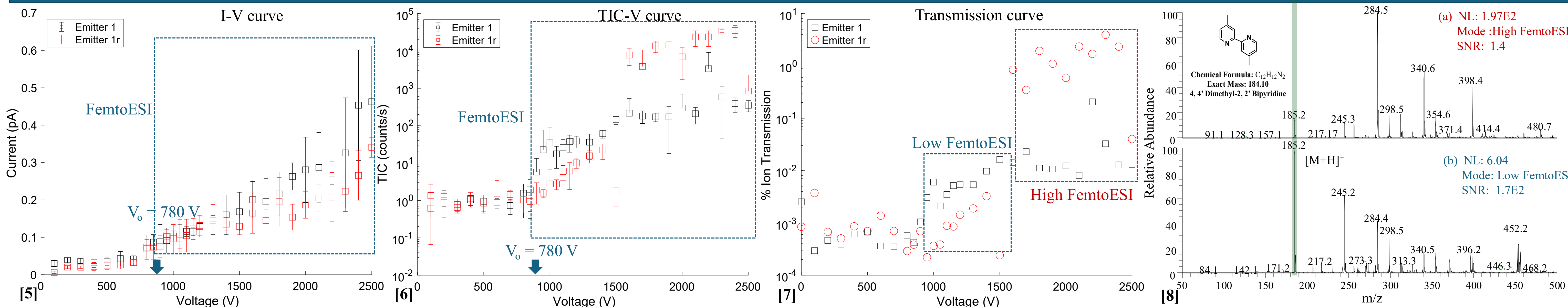


Figure 5. I-V and **Figure 6.** TIC-V curves for 10 μM 4,4'-Dimethyl-2,2'-bipyridine in toluene was repeated using same emitter shown as **1** (Black) and **1r** (Red). The normalized level of low femtoESI is (<10² cps) compared to high femtoESI [10²-10⁵ cps]. **Figure 7.** Percent ion transmission varies >3 orders of magnitude with highest transmission of ~4%. **Figure 8.** Mass spectrums (a) High femtoESI equivalent to ~500 fA current and (b) Low femtoESI equivalent to ~100 fA current. The signal-to-noise ratio enhancement is ~74 times.

Conclusions:

- The I-V and TIC-V curves were collected with offline measurements and aligned, to produce ion transmission efficiency as a function of the applied voltage.
- The ion transmission efficiency trends effectively characterize different ESI modes.
- For the non-conventional ESI solution of toluene, femtoESI was found to be composed of distinct high and low current sub-modes, though no nanoampere current was observed.
- In low femtoESI, signal-to-noise ratio for the BiPy analyte in toluene is ~72 times higher than that of high femtoESI, which has the best transmission efficiency ~4%.
- For the alkyl ammonium analyte, the femtoESI produces signal-to-noise ratio ~139 times that of nanoESI.
- The ionization onset (femtoESI) was 580 V for aqueous solution, 780 V for toluene solution, and 950 V for 200 mM ammonium acetate aqueous solution.
- Protein peaks with different degree of adduct and background was found in the femtoESI and nanoESI modes.

Acknowledgements:

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References:

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