ICP Source with Immersed Ferromagnetic Inductor - ICPIFI

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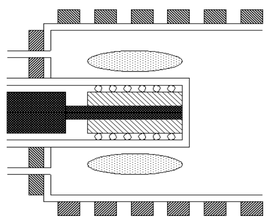
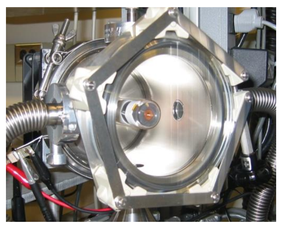
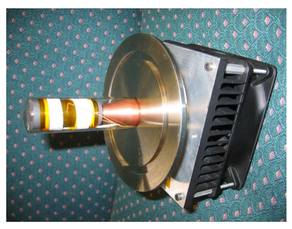
Application of ferromagnetics in inductively coupled plasma (ICP) sources results in many attractive features comparing to traditional ICPs without ferromagnetic cores [1,2]

Simple construction, high power factor (≤ 0.4) and power transfer efficiency (≤ 0.99), and no plasma RF potential and external EMI are advantageous features of ICPIFI

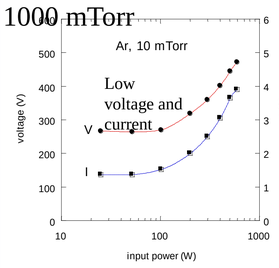
High performance of ICPIFI is due to strong coupling provided by the ferrite core making the ICP operation close to that of an ideal transformer. Moreover, the ICPIFI efficiency can exceed efficiency of conventional 60 Hz transformer! Due to low Q -factor, $Q = (\mathrm{Cos}\varphi^{-2} - 1)^{1/2} \geq 2.3$, there is no need for tuning. The tuning-matching network consists of just a single resonating permanent capacitor in series with the inductor coil.

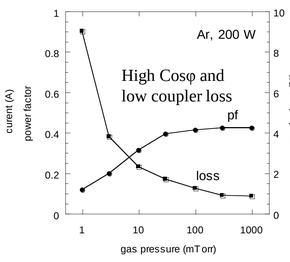


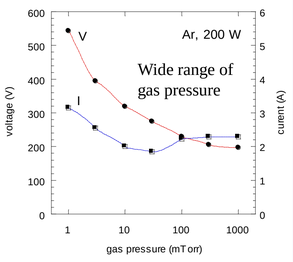


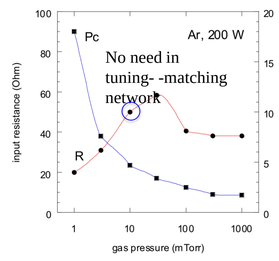


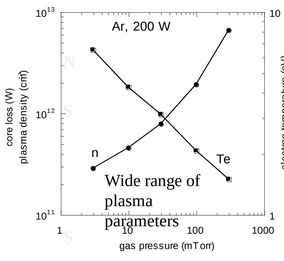
12 cm x 10 cm OD chamber, 3 MHz, 25-600 W, argon gas flow, p = 1-1000 mTorr

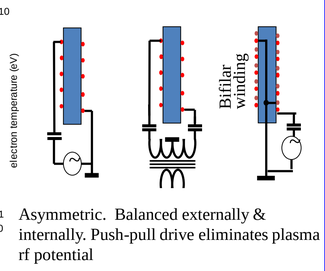






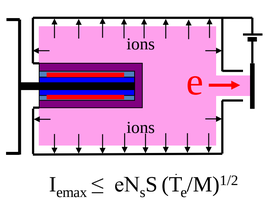




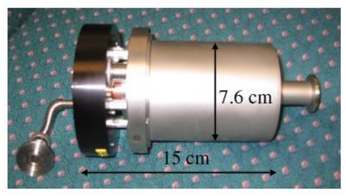


Asymmetric. Balanced externally & internally. Push-pull drive eliminates plasma rf potential

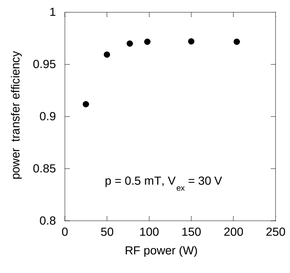
The simplest and most efficient plasma cathode, working in PPPL[3]

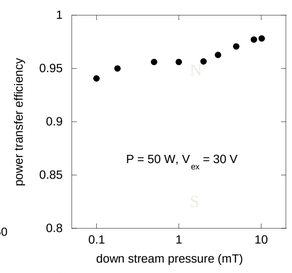


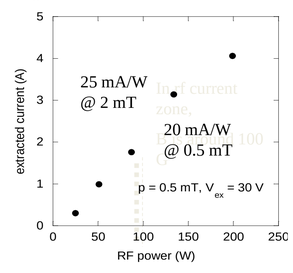
$I_{emax} \leq eN_sS\,(T_e/M)^{1/2}$



Advantages of RF plasma cathode: long operation life (no sputtering and evaporation), can be exposed to air, ability to operate in dirty processing gases and fast start. In ICPIFI $I_e \sim P$, (no excessive power at small I_e, while the thermionic cathode requires $P_h \approx$ const)







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1. V. Godyak, Ion-Beam Source, ***US Patent 7,863,582 B2***, *Jan 4, 2011*.
2. V. Godyak, Ferromagnetic Enhanced Inductive Plasma Sources, J. Phys. D: Appl. Phys. **46** (2013) 283001 (23pp).
3. V. Godyak, et al, RF Plasma Cathode-Neutralizer for Space Applications, *IEPC-2007-266, 30th Electric Propulsion Conf., Sept, 2007, Florence, Italy.*

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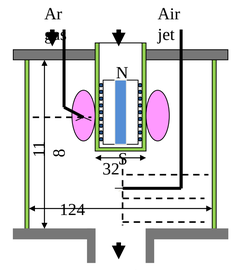
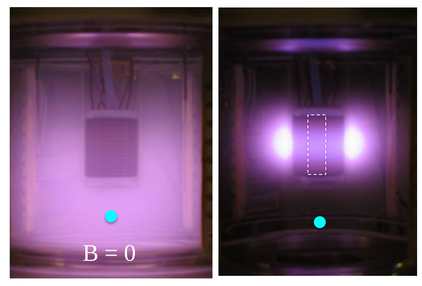
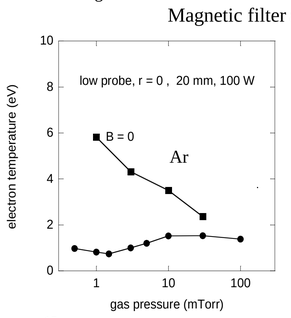
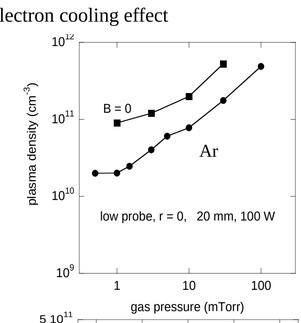
ICP with global magnetic filter as potential source of negative hydrogen ions

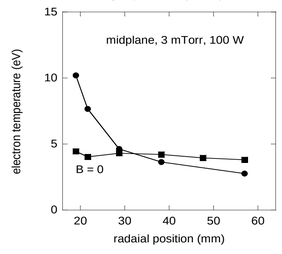


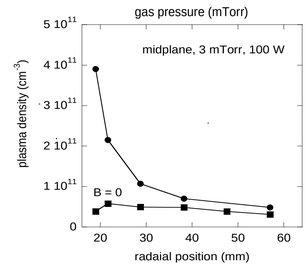


Magnetic filter and electron cooling effect









Instead of making large plasma with tiny area of magnetic filtering near the ion extraction aperture, the ICPIFI approach utilizes global plasma confinement with trapping of fast electron. Global plasma confinement reduces plasma loss, thus, improves plasma production and increase plasma volume with cold electron. That features of ICPIFI should be interesting for negative hydrogen ion production.