

## **Second Harmonic Breakdown in KSTAR**

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An 84-GHz electron cyclotron heating (ECH) system is being installed on the KSTAR tokamak. KSTAR adopts ECH-assisted start-up for the flexibility and reliability of the KSTAR operation with the plasma breakdown voltage reduced. The available maximum power of the 84 GHz ECH system is presently 500 kW with maximum duration of 2 s. A plasma breakdown voltage in range of 4 V to 5 V is needed when the fundamental harmonic EC-wave is used. Currently, the second harmonic ECH-assisted start-up is under consideration because a low toroidal field of  $B_T \sim 1.5$  T is desirable for safety and also for the high-beta experiments in the initial operation phase. There have been limited studies of efficacy of second harmonic breakdown. The studies in this paper are on the effectiveness of the second harmonic breakdown and alternatives to it for KSTAR. The optimum and threshold conditions for its successful start-up are calculated using a 0-D time dependent plasma evolution code. The power threshold in this calculation is compared with the recent DIII-D experimental results [1] on second harmonic pre-ionization where 60 GHz EC power was used. The ionization growth rate, which was used for the comparison with ITER 2<sup>nd</sup> harmonic pre-ionization in G. L. Jackson's [2] theoretical model in the DIII-D experiment, is also compared with KSTAR 2<sup>nd</sup> harmonic breakdown at 84 GHz.

[1] G. L. Jackson, J. S. Degraessie, J. Lohr, C. P. Moeller, R. Prater, et al., *Bull. Am. Phys. Soc.* 51, abstr.UP1.00026 (2006).

[2] G. L. Jackson, et al., submitted to *Nuclear Fusion* (2006).