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OBSERVATION OF NONLINEAR COUPLING OF WAVES EXCITED AT DISTINCT REGIONS OF OVERLAPPING DUAL LOWER HYBRID AND ION CYCLOTRON RESONANCES

Hiroe IGAMI[1], Mieko TOIDA[1], Atsushi FUKUYAMA[2], Shigeru INAGAKI[3], Ryosuke Seki[1,4], Hiroyuki YAMAGUCHI[1,4], and Yuto KATOH[5]

[1]National Institute for Fusion Science, [2]Graduate School of Engineering Kyoto University, [3]Institute of Advanced Energy Kyoto University, [4]The Graduate University for Advanced Studies, [5]Graduate School of Science Tohoku University

igami.hiroe@nifs.ac.jp

ABSTRACT

- Burst-like emissions in the lower hybrid (LH) frequency (f_0) and its harmonic frequency ranges were observed in the large helical device (LHD)
- LH and its harmonic range waves (lf_0) nonlinearly coupled with the sidebands ($mf_0 \pm nf_1$, $mf_0 \pm nf_2$) characterized by f_1 and f_2 in ion cyclotron (IC) frequency range
- Two spatially separated "dual resonances", namely DR1 and DR2 were identified. The LH resonance (LHR) of f_0 overlaps with the IC resonance (ICR) of f_1 at DR1 and the LHR of f_0 overlaps with the ICR of f_2 at DR2
- Waves, which can potentially contribute to the resonant heating of bulk ions, spontaneously can grow nonlinearly due to the presence of high-energy ions and distinct spatially separated dual resonances

BACKGROUND

- Finding a scenario where fusion born alpha particles excite waves that resonantly heat bulk ions, leads efficient sustainment of the burning plasma
- Interaction of alpha particles with lower hybrid (LH) waves and ion Bernstein waves in fusion plasmas have been studied theoretically
- Observation of instabilities excited by energetic ions in LH, IC harmonic frequency ranges are important to study energy cascade process via waves that can resonantly heat bulk ions

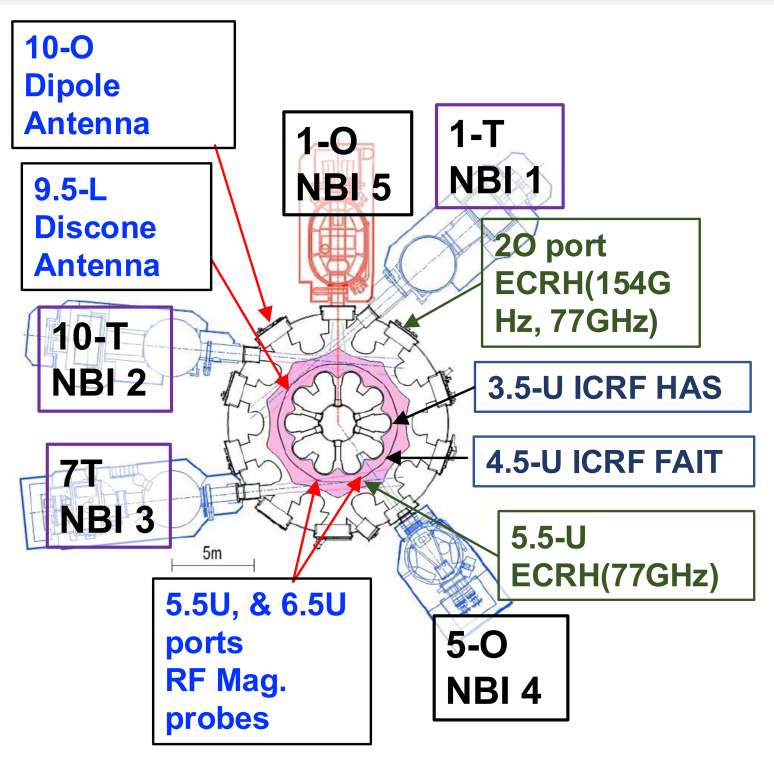
METHODS

OBSERVATION OF RF EMISSIONS EXCITED BY BEAM DRIVEN IONS

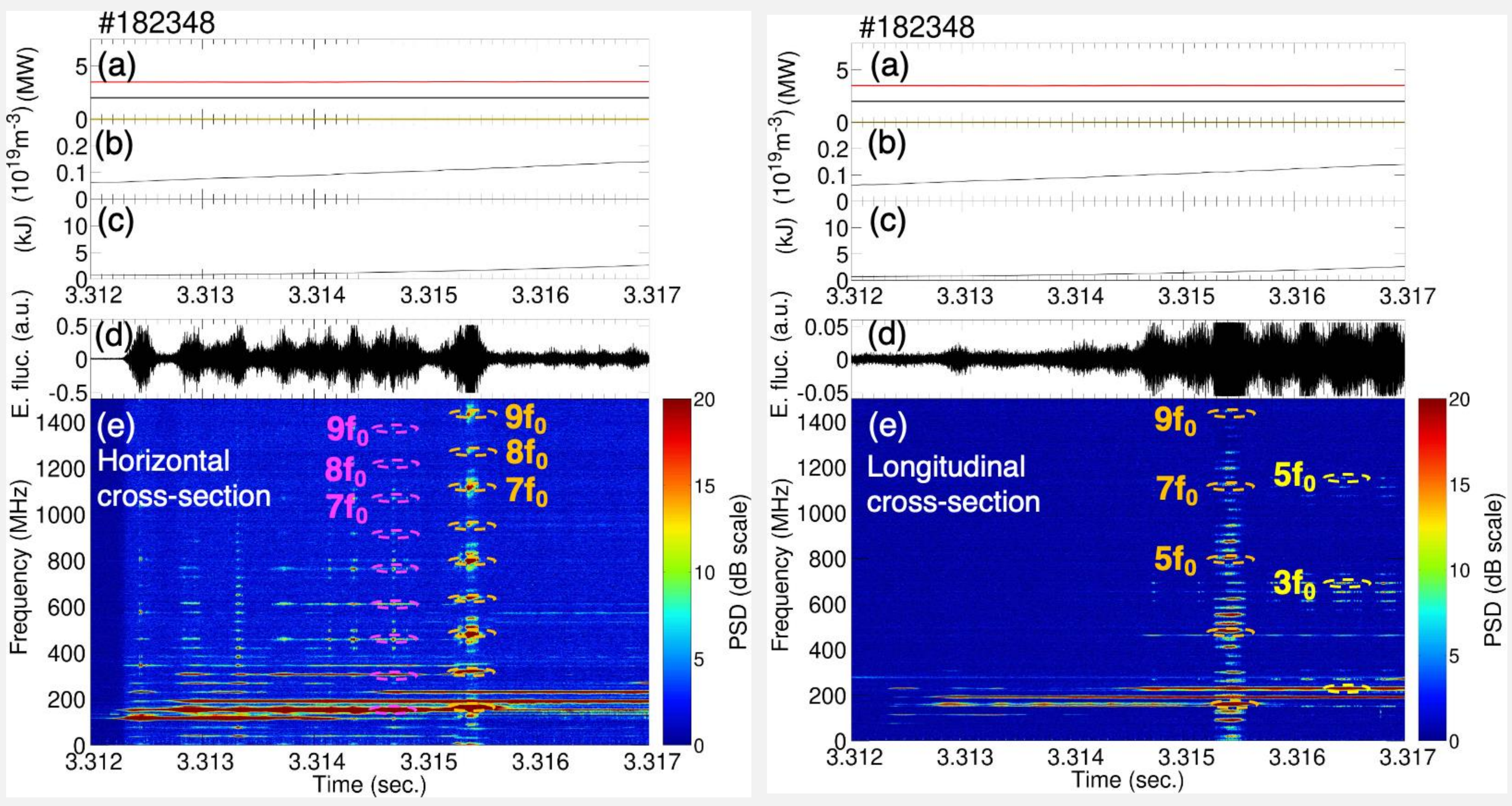
is instructive for studying the energy cascade process of alpha particles via waves

EXPERIMENTAL CONDITION

Electric fluctuations and spectrograms were detected by dipole and discone antennas during start-up phase of the plasma with tangential hydrogen NBI with 164 keV/3.86 MW and ECRH with 154 GHz/2.0 MW in total with magnetic configuration (R_{ax}, B_t)=(3.6m, 2.75T)



Locations of heating systems and RF antennas installed in LHD

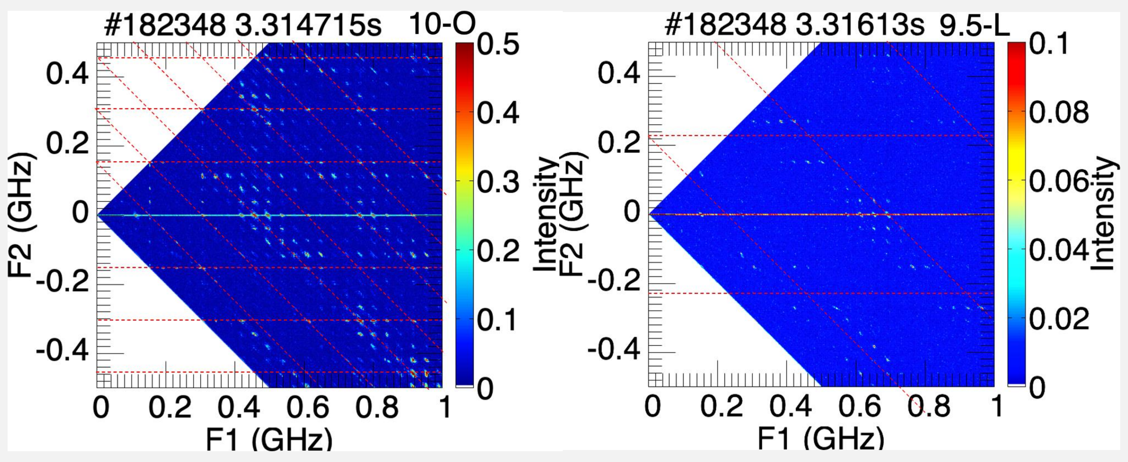


Time change of (a) heating power, (b) line averaged density, (c) stored energy, (d) electric fluctuation signal and (e) frequency spectrogram

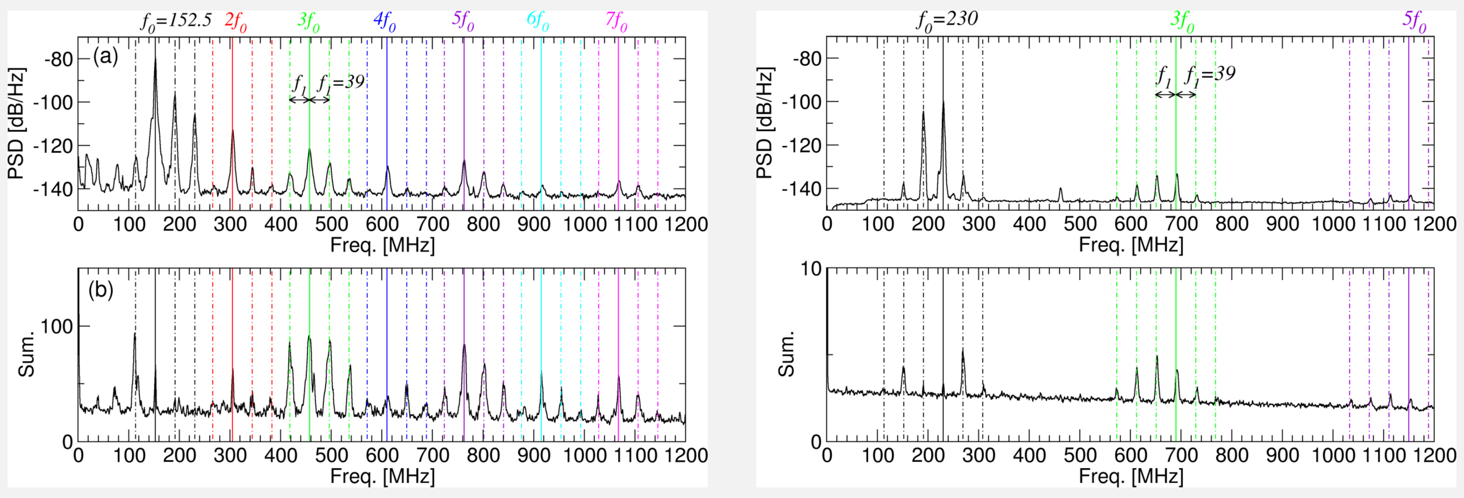
OUTCOME

INTERACTIONS BETWEEN EXCITED WAVES DURING BURSTS

- Interactions between sidebands characterized by f_1 around odd and even harmonics of f_0 are strong. As a result, the spectrum of the sum of bicoherence shows peaks around odd harmonics



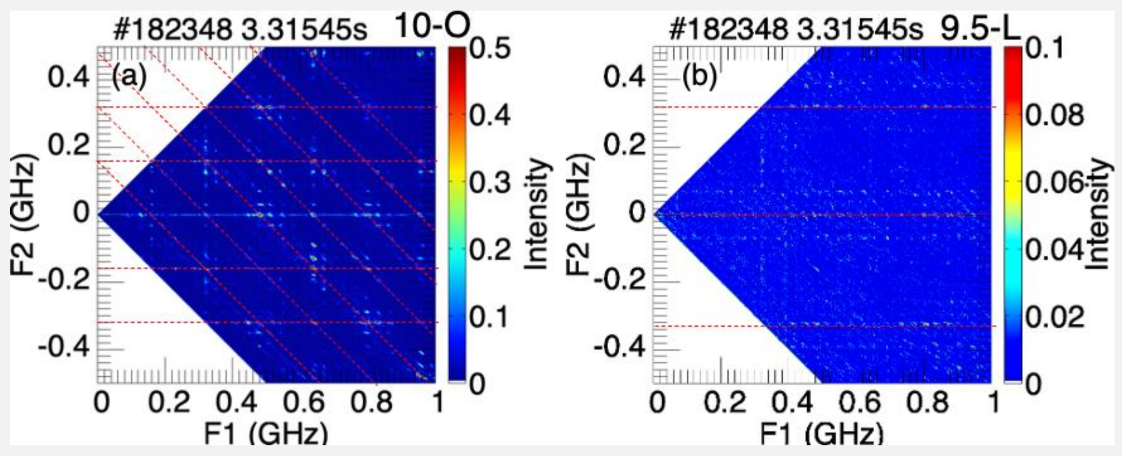
Auto bicoherences of electric fluctuations during bursts



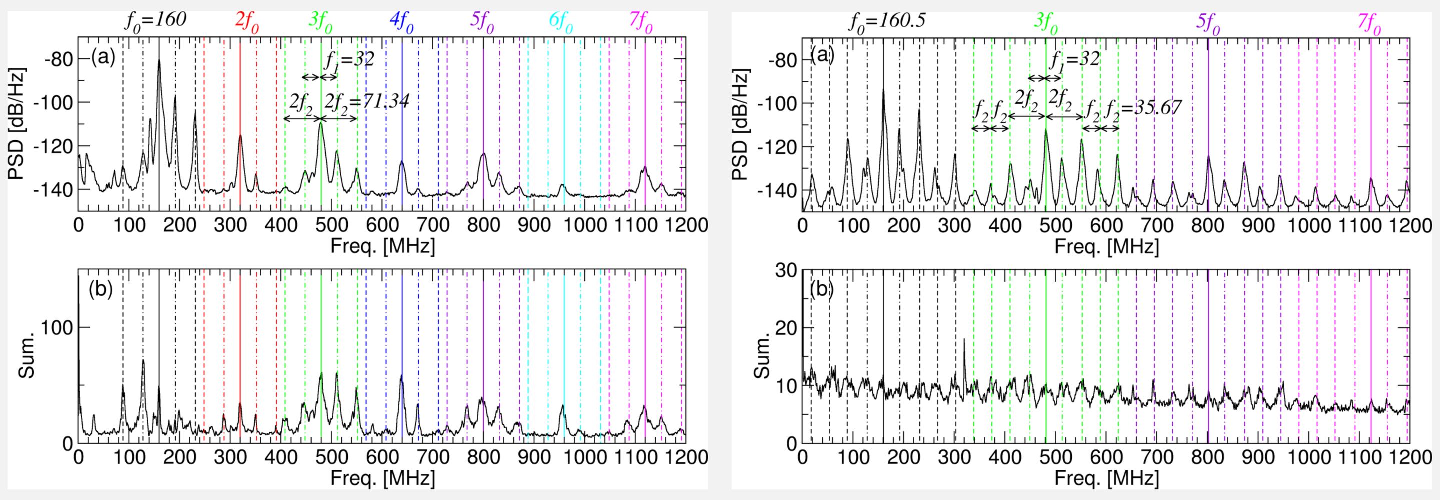
Power spectrum and total sum of auto bicoherence

INTERACTIONS BETWEEN EXCITED WAVES DURING THE LARGEST BURST

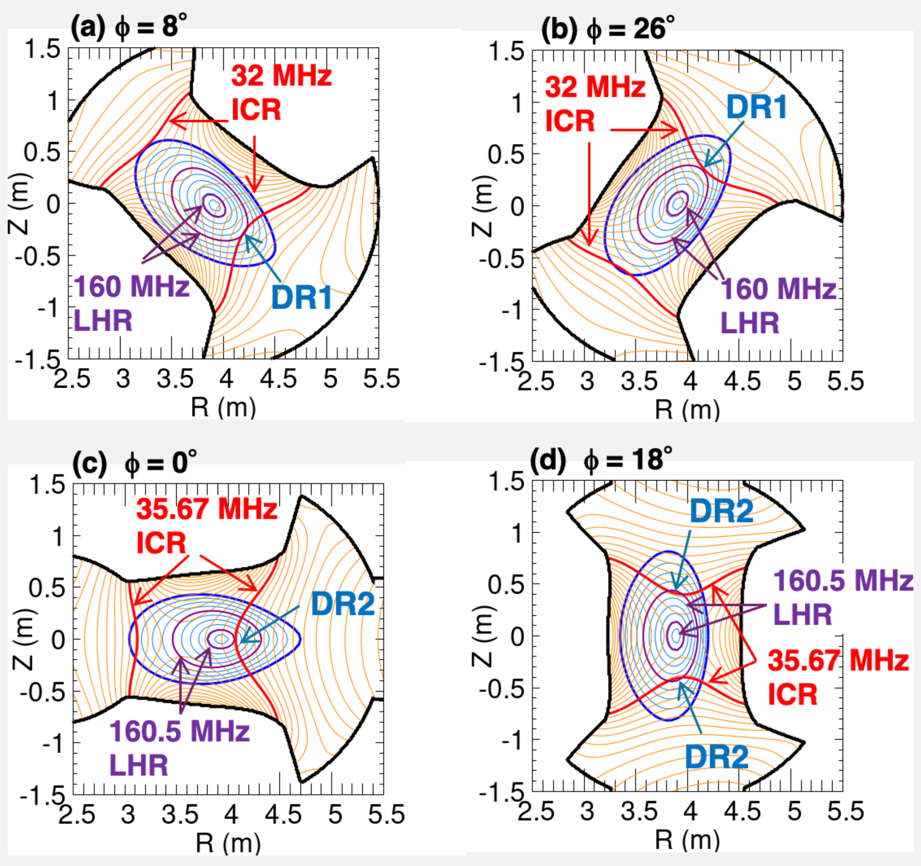
- Both of sidebands characterized by f_1 and f_2 interact with nf_0
- Dual resonances of LHR (f_0) - ICR (f_1), and LHR (f_0) - ICR (f_2) exist periodically every 18° in the torus



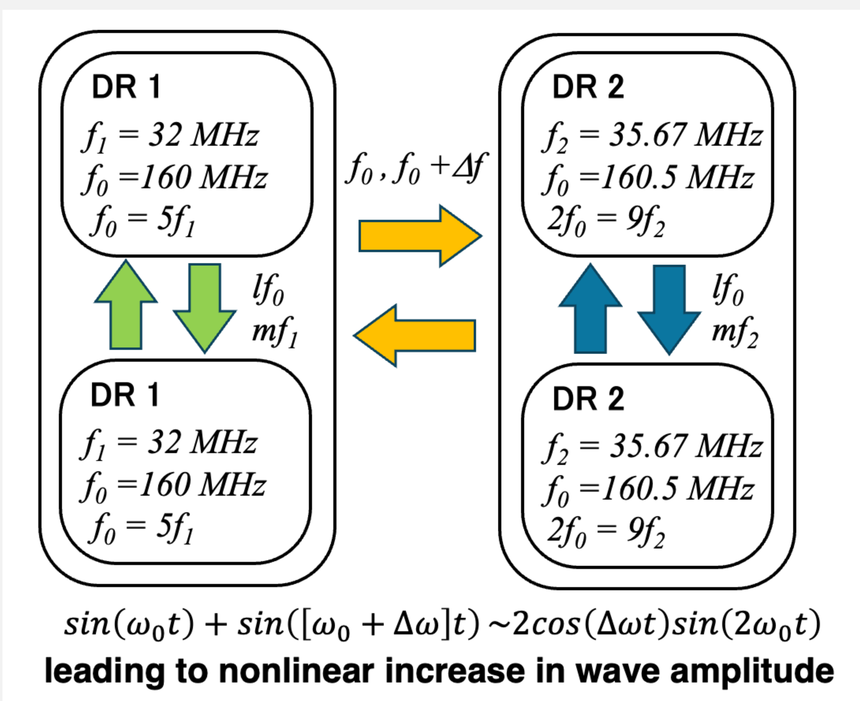
Auto bicoherences of electric fluctuations during the largest burst



Power spectrum and total sum of auto bicoherence



Locations of LHR and ICR



Conceptual diagram of bursty amplitude modulation at twice the resonant frequencies

CONCLUSION

- This study demonstrated the potential to enhance the growth of waves, that contribute to the resonant heating of bulk ions, by establishing multiple dual resonances at distinct locations in the presence of energetic ions in MCF plasmas.