Suppression of large edge localized modes with edge resonant magnetic fields in high confinement DIII-D plasmas

T.E. Evans , R.A. Moyer[a)], J.G. Watkins[b)], T.H. Osborne, P.R. Thomas[c)], M. Becoulet[c)], J.A. Boedo[b)], E.J. Doyle[d)], M.E. Fenstermacher [e)], K.H. Finken[f)], R.J. Groebner, M. Groth[e)], J.H. Harris[g)], G.L. Jackson, R.J. La Haye, C.J. Lasnier[e)], S. Masuzaki[h)], N. Ohyabu[h)], D.G. Pretty[g)], H. Reimerdes[i)], T.L. Rhodes[d)], D.L. Rudakov[a)], M.J. Schaffer, M.R. Wade[j)], G. Wang[d)], W.P. West, and L. Zeng [d)]

General Atomics, P.O. Box 85608, San Diego, California, 92186-5608 U.S.A.
[a)]University of California San Diego, La Jolla, California, U.S.A.
[b)]Sandia National Laboratory, Albuquerque, New Mexico, U.S.A.
[c)]CEA-Cadarache Euratom Association, Cadarache, France
[d)]University of California, Los Angeles, California, U.S.A.
[e)]Lawrence Livermore National Laboratory, Livermore, California, U.S.A.
[f)]FZ-Jülich Euratom Association, Jülich, Germany
[g)]Australian National University, Canberra, Australia
[h)]National Institute for Fusion Science, Gifu-ken, Japan
[i)]Columbia University, New York, New York, U.S.A.
[j)]Oak Ridge National Laboratory, Oak Ridge, Tennessee, U.S.A.

email: evans@fusion.gat.com

Abstract. Large sub-millisecond heat pulses due to Type-I edge localized modes (ELMs) have been eliminated reproducibly in DIII-D for periods approaching nine energy confinement times (τ_E) with small dc currents driven in a simple magnetic perturbation coil. The current required to eliminate all but a few isolated Type-I ELM impulses during a coil pulse is less than 0.4% of plasma current. Based on vacuum magnetic field line modeling, the perturbation fields resonate with plasma flux surfaces across most of the pedestal region ($0.9 \leq \psi_N \leq 1.0$) when $q_{95} = 3.7 \pm 0.2$ creating small remnant magnetic islands surrounded by weakly stochastic field lines. The stored energy, β_N, H–mode quality factor and global energy confinement time are unaltered by the magnetic perturbation. Although some isolated ELMs occur during the coil pulse, long periods free of large Type-I ELMs (Δt > 4-6 τ_E) have been reproduced numerous times, on multiple experimental run days in high and intermediate triangularity plasmas including cases matching the baseline ITER Scenario 2 flux surface shape. In low triangularity, lower single null, plasmas with collisionalities near that expected in ITER, Type-I ELMs are replaced by small amplitude, high frequency Type-II-like ELMs and are often accompanied by one or more ELM-free periods approaching 1-2 τ_E. Large Type-I ELM impulses represent a severe constraint on the survivability of the divertor target plates in future burning plasma devices. Results presented in this paper demonstrate that non-axisymmetric edge magnetic perturbations provide a very attractive development path for active ELM control in future tokamaks such as ITER.