CLAIMS

1. A drilling module comprising:

a rotary drill-bit ~~(1)~~;

an oscillator configured to apply high frequency axial oscillatory loading to the rotary drill-bit, of up to 1 kHz;

a vibro-transmission section connecting the rotary drill-bit and the oscillator, the vibro-transmission section configured to transmit the high frequency axial oscillatory loading from the oscillator to the rotary drill-bit;

a vibrational isolation unit for connecting the drilling module to a drill-string, the vibrational isolation unit being configured to isolate the high frequency axial oscillatory loading from the drill-string;

sensors for taking downhole measurements; and

a closed loop real-time controller positioned downhole and configured to operate downhole under closed loop real-time control by utilizing the downhole measurements from the sensors to control the oscillator by varying the high frequency axial oscillatory loading responsive to conditions of material through which the rotary drill-bit is passing to establish and maintain oscillation system resonance between the oscillator, the rotary drill-bit and the material through which the rotary drill-bit is passing whereby the high frequency axial oscillatory loading is sufficient to initiate cracks in the material through which the rotary drill-bit is passing.

2. A drilling module according to claim 1, wherein the controller is configured to sweep a frequency range to evaluate conditions of the material through which the rotary drill-bit is passing to establish and maintain

oscillation system resonance.

3. A drilling module according to any preceding claim, wherein the oscillator is configured to apply high frequency axial oscillatory loading based on a basic resonance curve for the rotary drill-bit and modify the high frequency axial oscillatory loading to take into account interactions with the material being drilled.

4. A drilling module according to any preceding claim, wherein the controller is configured to determining appropriate loading parameters for the rotary drill-bit according to the following steps in order to achieve and maintain oscillation system resonance:

A) determine a limit of amplitude of the rotary drill-bit when resonating and interacting with the material being drilled;

B) estimate a suitable frequency sweeping range for loading the drill-bit;

C) estimate the shape of a resonance curve;

D) choose an optimum resonant frequency on the resonance curve at a point less than the maximum on the resonance curve; and

E) drive the rotary drill-bit based on this optimum resonant frequency.

5. A drilling module according to any preceding claim, wherein the controller is configured to autonomously adjust rotational and high frequency axial oscillatory loading of the rotary drill-bit in response to current drilling conditions.

6. A drilling module according to claim 5, wherein the controller is configured to control the rotary drill-bit to impact on the material through which the rotary drill bit

is passing to produce a first set of macro-cracks, the controller being further configured to control the rotary drill-bit to rotate and impact on the material a further occasion to produce a further set of macro-cracks, the controller being configured to synchronize rotational and oscillatory movements of the rotary drill-bit for promoting interconnection of the macro-cracks thus produced, to create a localized dynamic crack propagation zone ahead of the rotary drill-bit.

7. A method for controlling a resonance enhanced rotary drill comprising a rotary drill-bit and an oscillator for applying high frequency axial oscillatory loading to the rotary drill-bit of up to 1 kHz, the method comprising:

applying high frequency axial oscillatory loading to the rotary drill-bit;

taking downhole measurements;

controlling the applied high frequency axial oscillatory loading downhole under closed loop real-time control by utilizing the downhole measurements to vary the high frequency axial oscillatory loading responsive to conditions of material through which the rotary drill-bit is passing to establish and maintain oscillation system resonance between the oscillator, the rotary drill-bit and the material through which the rotary drill-bit is passing whereby the high frequency axial oscillatory loading is sufficient to initiate cracks in the material through which the rotary drill-bit is passing.

8. A method according to claim 7, further comprising:

sweeping a frequency range to evaluate conditions of the material through which the rotary drill-bit is passing to establish and maintain oscillation system resonance.

9. A method according to claim 7 or 8, wherein the high

frequency axial oscillatory loading is applied based on a basic resonance curve for the rotary drill-bit and the high frequency axial oscillatory loading is modified to take into account interactions with the material being drilled.

10. A method according to any one of claims 7 to 9, further comprising determining appropriate loading parameters for the rotary drill-bit according to the following steps in order to achieve and maintain oscillation system resonance:

A) determine a limit of amplitude of the rotary drill-bit when resonating and interacting with the material being drilled;

B) estimate a suitable frequency sweeping range for loading the drill-bit;

C) estimate the shape of a resonance curve;

D) choose an optimum resonant frequency on the resonance curve at a point less than the maximum on the resonance curve; and

E) drive the rotary drill-bit based on this optimum resonant frequency.

11. A method according to any one of claims 7 to 10, wherein the rotational and high frequency axial oscillatory loading of the rotary drill-bit are adjust autonomously in response to current drilling conditions.

12. A method according to claim 11, wherein the rotary drill-bit is controlled to impact on the material through which the rotary drill bit is passing to produce a first set of macro-cracks, and to rotate and impact on the material a further occasion to produce a further set of macro-cracks, the rotational and oscillatory movements of the rotary drill-bit being synchronized to promote interconnection of the macro-cracks thus produced, to

create a localized dynamic crack propagation zone ahead of the rotary drill-bit.

13. A control apparatus configured to perform the method of any one of claims 7 to 12 when mounted in a drilling module ~~according to any one of claims 1 to 6.~~ comprising:

a rotary drill-bit;

an oscillator configured to apply high frequency axial oscillatory loading to the rotary drill-bit, of up to 1 kHz;

a vibro-transmission section connecting the rotary drill-bit and the oscillator, the vibro-transmission section configured to transmit the high frequency axial oscillatory loading from the oscillator to the rotary drill-bit;

a vibrational isolation unit for connecting the drilling module to a drill-string, the vibrational isolation unit being configured to isolate the high frequency axial oscillatory loading from the drill-string;

sensors for taking downhole measurements; and

a controller configured to operate downhole under closed loop real-time control by utilizing the downhole measurements from the sensors to control the oscillator by varying the high frequency axial oscillatory loading responsive to conditions of material through which the rotary drill-bit is passing to establish and maintain oscillation system resonance between the oscillator, the rotary drill-bit and the material through which the rotary drill-bit is passing whereby the high frequency axial oscillatory loading is sufficient to initiate cracks in the material through which the rotary drill-bit is passing.