WHAT IS CLAIMED IS:

1. A foreign substance removal apparatus comprising:

an optical member;

a piezoelectric element attached to the optical member;

a drive control unit configured to drive the piezoelectric element in a first driving mode for exciting a first bending vibration of the optical member, a second driving mode for exciting a second bending vibration of the optical member, and a third driving mode for simultaneously exciting the first bending vibration and the second bending vibration, the second bending vibration having an order different from an order of the first bending vibration;

a vibration detection unit configured to detect a vibration of the optical member when the drive control unit drives the piezoelectric element in the first driving mode and the second driving mode; and

a driving parameter generation unit configured to determine a driving parameter for when the drive control unit drives the piezoelectric element in the third driving mode based on a time phase difference between a vibration of the optical member which is detected when the drive control unit drives the piezoelectric element in the first driving mode, and a vibration of the optical member which is detected when the drive control unit drives the piezoelectric element in the second driving mode,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter determined by the driving parameter generation unit.

2. The foreign substance removal apparatus according to claim 1,

wherein a drive electrode and a sensor electrode are formed at the piezoelectric element,

wherein the drive control unit is configured to drive the piezoelectric element by applying a voltage to the drive electrode, and

wherein the vibration detection unit is configured to detect the vibration of the optical member from an output from the sensor electrode.

3. The foreign substance removal apparatus according to claim 2,

wherein the piezoelectric element includes a first piezoelectric element provided at one end of the optical member, and a second piezoelectric element provided at the other end of the optical member,

wherein a first drive electrode and a first sensor electrode are formed at the first piezoelectric element,

wherein a second drive electrode is formed at the second piezoelectric element,

wherein the drive control unit is configured to apply

voltages in a same phase to the first drive electrode and the second drive electrode, both when the drive control unit drives the first piezoelectric element and the second piezoelectric element in the first driving mode and when the drive control unit drives the first piezoelectric element and the second piezoelectric element in the second driving mode, and

wherein the vibration detection unit is configured to detect the vibration of the optical member from an output of the first sensor electrode, both when the drive control unit drives the piezoelectric element in the first driving mode and when the drive control unit drives the piezoelectric element in the second driving mode.

4. The foreign substance removal apparatus according to claim 1,

wherein the drive control unit is configured to apply a first voltage to the piezoelectric element when the drive control unit drives the piezoelectric element in the first driving mode and the second driving mode,

wherein the drive control unit is configured to apply a second voltage to the piezoelectric element when the drive control unit drives the piezoelectric element in the third driving mode, and

wherein the first voltage is lower than the second voltage.

5. The foreign substance removal apparatus according to

claim 1,

wherein the drive control unit is configured to drive the piezoelectric element for a first driving time when the drive control unit drives the piezoelectric element in the first driving mode and in the second driving mode,

wherein the drive control unit is configured to drive the piezoelectric element for a second driving time when the drive control unit drives the piezoelectric element in the third driving mode, and

wherein the first driving time is shorter than the second driving time.

6. The foreign substance removal apparatus according to claim 1, further comprising a memory configured to store the driving parameter set by the driving parameter generation unit; and

a time counter unit configured to measure an elapsed time since the drive control unit drives the piezoelectric element in the third driving mode,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter stored in the memory without causing the driving parameter generation unit to operate, in a case where the elapsed time measured by the time counter unit is within a predetermined range.

7. The foreign substance removal apparatus according to

claim 1, further comprising:

a temperature detection unit configured to detect an ambient temperature around the optical member; and

a memory configured to store the driving parameter set by the driving parameter generation unit in association with the temperature detected by the temperature detection unit,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter stored in the memory without causing the driving parameter generation unit to operate, in a case where the temperature detected by the temperature detection unit when the drive control unit is caused to operate is within a predetermined range set based on the temperature stored in the memory.

8. An optical apparatus comprising:

an optical member;

a piezoelectric element attached to the optical member;

a drive control unit configured to drive the piezoelectric element in a first driving mode for exciting a first bending vibration of the optical member, a second driving mode for exciting a second bending vibration of the optical member, and a third driving mode for simultaneously exciting the first bending vibration and the second bending vibration, the second bending vibration having an order different from an order of the first bending vibration;

a vibration detection unit configured to detect a vibration of the optical member when the drive control unit drives the piezoelectric element in the first driving mode and in the second driving mode; and

a driving parameter generation unit configured to determine a driving parameter for when the drive control unit drives the piezoelectric element in the third driving mode based on a time phase difference between a vibration of the optical member which is detected when the drive control unit drives the piezoelectric element in the first driving mode, and a vibration of the optical member which is detected when the drive control unit drives the piezoelectric element in the second driving mode,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter determined by the driving parameter generation unit.

9. The optical apparatus according to claim 8,

wherein a drive electrode and a sensor electrode are formed at the piezoelectric element,

wherein the drive control unit is configured to drive the piezoelectric element by applying a voltage to the drive electrode, and

wherein the vibration detection unit is configured to detect the vibration of the optical member from an output from the sensor electrode.

10. The optical apparatus according to claim 9,

wherein the piezoelectric element includes a first piezoelectric element provided at one end of the optical member, and a second piezoelectric element provided at the other end of the optical member,

wherein a first drive electrode and a first sensor electrode are formed at the first piezoelectric element,

wherein a second drive electrode is formed at the second piezoelectric element,

wherein the drive control unit is configured to apply voltages in a same phase to the first drive electrode and the second drive electrode, both when the drive control unit drives the first piezoelectric element and the second piezoelectric element in the first driving mode and when the drive control unit drives the first piezoelectric element and the second piezoelectric element in the second driving mode, and

wherein the vibration detection unit is configured to detect the vibration of the optical member from an output of the first sensor electrode, both when the drive control unit drives the piezoelectric element in the first driving mode and when the drive control unit drives the piezoelectric element in the second driving mode.

11. The optical apparatus according to claim 8,

wherein the drive control unit is configured to apply a first voltage to the piezoelectric element when the drive

control unit drives the piezoelectric element in the first driving mode and the second driving mode,

wherein the drive control unit is configured to apply a second voltage to the piezoelectric element when the drive control unit drives the piezoelectric element in the third driving mode, and

wherein the first voltage is lower than the second voltage.

12. The optical apparatus according to claim 8,

wherein the drive control unit is configured to drive the piezoelectric element for a first driving time when the drive control unit drives the piezoelectric element in the first driving mode and the second driving mode,

wherein the drive control unit is configured to drive the piezoelectric element for a second driving time when the drive control unit drives the piezoelectric element in the third driving mode, and

wherein the first driving time is shorter than the second driving time.

13. The optical apparatus according to claim 8, further comprising a memory configured to store the driving parameter set by the driving parameter generation unit; and

a time counter unit configured to measure an elapsed time since the drive control unit drives the piezoelectric element in the third driving mode,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter stored in the memory without causing the driving parameter generation unit to operate, in a case where the elapsed time measured by the time counter unit is within a predetermined range.

14. The optical apparatus according to claim 8, further comprising:

a temperature detection unit configured to detect an ambient temperature around the optical member; and

a memory configured to store the driving parameter set by the driving parameter generation unit in association with the temperature detected by the temperature detection unit,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter stored in the memory without causing the driving parameter generation unit to operate, in a case where the temperature detected by the temperature detection unit when the drive control unit is caused to operate is within a predetermined range set based on the temperature stored in the memory.

WHAT IS CLAIMED IS:

1. A foreign substance removal apparatus comprising:

an optical member;

a piezoelectric element attached to the optical member;

a drive control unit configured to drive the piezoelectric element in a first driving mode for exciting a first bending vibration of the optical member, a second driving mode for exciting a second bending vibration of the optical member, and a third driving mode for simultaneously exciting the first bending vibration and the second bending vibration, the second bending vibration having an order different from an order of the first bending vibration;

a vibration detection unit configured to detect a vibration of the optical member when the drive control unit drives the piezoelectric element in the first driving mode and the second driving mode; and

a driving parameter generation unit configured to determine a driving parameter for when the drive control unit drives the piezoelectric element in the third driving mode based on a time phase difference between a vibration of the optical member which is detected when the drive control unit drives the piezoelectric element in the first driving mode, and a vibration of the optical member which is detected when the drive control unit drives the piezoelectric element in the second driving mode,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter determined by the driving parameter generation unit.

2. The foreign substance removal apparatus according to claim 1,

wherein a drive electrode and a sensor electrode are formed at the piezoelectric element,

wherein the drive control unit is configured to drive the piezoelectric element by applying a voltage to the drive electrode, and

wherein the vibration detection unit is configured to detect the vibration of the optical member from an output from the sensor electrode.

3. The foreign substance removal apparatus according to claim 2,

wherein the piezoelectric element includes a first piezoelectric element provided at one end of the optical member, and a second piezoelectric element provided at the other end of the optical member,

wherein a first drive electrode and a first sensor electrode are formed at the first piezoelectric element,

wherein a second drive electrode is formed at the second piezoelectric element,

wherein the drive control unit is configured to apply

voltages in a same phase to the first drive electrode and the second drive electrode, both when the drive control unit drives the first piezoelectric element and the second piezoelectric element in the first driving mode and when the drive control unit drives the first piezoelectric element and the second piezoelectric element in the second driving mode, and

wherein the vibration detection unit is configured to detect the vibration of the optical member from an output of the first sensor electrode, both when the drive control unit drives the piezoelectric element in the first driving mode and when the drive control unit drives the piezoelectric element in the second driving mode.

4. The foreign substance removal apparatus according to claim 1,

wherein the drive control unit is configured to apply a first voltage to the piezoelectric element when the drive control unit drives the piezoelectric element in the first driving mode and the second driving mode,

wherein the drive control unit is configured to apply a second voltage to the piezoelectric element when the drive control unit drives the piezoelectric element in the third driving mode, and

wherein the first voltage is lower than the second voltage.

5. The foreign substance removal apparatus according to

claim 1,

wherein the drive control unit is configured to drive the piezoelectric element for a first driving time when the drive control unit drives the piezoelectric element in the first driving mode and in the second driving mode,

wherein the drive control unit is configured to drive the piezoelectric element for a second driving time when the drive control unit drives the piezoelectric element in the third driving mode, and

wherein the first driving time is shorter than the second driving time.

6. The foreign substance removal apparatus according to claim 1, further comprising a memory configured to store the driving parameter set by the driving parameter generation unit; and

a time counter unit configured to measure an elapsed time since the drive control unit drives the piezoelectric element in the third driving mode,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter stored in the memory without causing the driving parameter generation unit to operate, in a case where the elapsed time measured by the time counter unit is within a predetermined range.

7. The foreign substance removal apparatus according to

claim 1, further comprising:

a temperature detection unit configured to detect an ambient temperature around the optical member; and

a memory configured to store the driving parameter set by the driving parameter generation unit in association with the temperature detected by the temperature detection unit,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter stored in the memory without causing the driving parameter generation unit to operate, in a case where the temperature detected by the temperature detection unit when the drive control unit is caused to operate is within a predetermined range set based on the temperature stored in the memory.

8. An optical apparatus comprising:

an optical member;

a piezoelectric element attached to the optical member;

a drive control unit configured to drive the piezoelectric element in a first driving mode for exciting a first bending vibration of the optical member, a second driving mode for exciting a second bending vibration of the optical member, and a third driving mode for simultaneously exciting the first bending vibration and the second bending vibration, the second bending vibration having an order different from an order of the first bending vibration;

a vibration detection unit configured to detect a vibration of the optical member when the drive control unit drives the piezoelectric element in the first driving mode and in the second driving mode; and

a driving parameter generation unit configured to determine a driving parameter for when the drive control unit drives the piezoelectric element in the third driving mode based on a time phase difference between a vibration of the optical member which is detected when the drive control unit drives the piezoelectric element in the first driving mode, and a vibration of the optical member which is detected when the drive control unit drives the piezoelectric element in the second driving mode,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter determined by the driving parameter generation unit.

9. The optical apparatus according to claim 8,

wherein a drive electrode and a sensor electrode are formed at the piezoelectric element,

wherein the drive control unit is configured to drive the piezoelectric element by applying a voltage to the drive electrode, and

wherein the vibration detection unit is configured to detect the vibration of the optical member from an output from the sensor electrode.

10. The optical apparatus according to claim 9,

wherein the piezoelectric element includes a first piezoelectric element provided at one end of the optical member, and a second piezoelectric element provided at the other end of the optical member,

wherein a first drive electrode and a first sensor electrode are formed at the first piezoelectric element,

wherein a second drive electrode is formed at the second piezoelectric element,

wherein the drive control unit is configured to apply voltages in a same phase to the first drive electrode and the second drive electrode, both when the drive control unit drives the first piezoelectric element and the second piezoelectric element in the first driving mode and when the drive control unit drives the first piezoelectric element and the second piezoelectric element in the second driving mode, and

wherein the vibration detection unit is configured to detect the vibration of the optical member from an output of the first sensor electrode, both when the drive control unit drives the piezoelectric element in the first driving mode and when the drive control unit drives the piezoelectric element in the second driving mode.

11. The optical apparatus according to claim 8,

wherein the drive control unit is configured to apply a first voltage to the piezoelectric element when the drive

control unit drives the piezoelectric element in the first driving mode and the second driving mode,

wherein the drive control unit is configured to apply a second voltage to the piezoelectric element when the drive control unit drives the piezoelectric element in the third driving mode, and

wherein the first voltage is lower than the second voltage.

12. The optical apparatus according to claim 8,

wherein the drive control unit is configured to drive the piezoelectric element for a first driving time when the drive control unit drives the piezoelectric element in the first driving mode and the second driving mode,

wherein the drive control unit is configured to drive the piezoelectric element for a second driving time when the drive control unit drives the piezoelectric element in the third driving mode, and

wherein the first driving time is shorter than the second driving time.

13. The optical apparatus according to claim 8, further comprising a memory configured to store the driving parameter set by the driving parameter generation unit; and

a time counter unit configured to measure an elapsed time since the drive control unit drives the piezoelectric element in the third driving mode,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter stored in the memory without causing the driving parameter generation unit to operate, in a case where the elapsed time measured by the time counter unit is within a predetermined range.

14. The optical apparatus according to claim 8, further comprising:

a temperature detection unit configured to detect an ambient temperature around the optical member; and

a memory configured to store the driving parameter set by the driving parameter generation unit in association with the temperature detected by the temperature detection unit,

wherein the drive control unit is configured to drive the piezoelectric element in the third driving mode with use of the driving parameter stored in the memory without causing the driving parameter generation unit to operate, in a case where the temperature detected by the temperature detection unit when the drive control unit is caused to operate is within a predetermined range set based on the temperature stored in the memory.